Received 31 May 2023
Revised 2 August 2023
7 October 2023
17 December 2023
Accepted 17 December 2023

Investigating the impact of the Internet of Things on higher education: a systematic literature review

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Abstract

Purpose – The Internet of things (IoT), an emerging research field, offers solutions to several problems and may result in a paradigm shift in various areas, including education. However, this approach has been under-utilised. Therefore, this research investigates and highlights the primary factors that influence the impact of the IoT on education and reveals the current state of academic research to manage higher education (HE) resources effectively and efficiently.

Design/methodology/approach – Data from 35 academic papers were collected and analysed to understand the current situation and assess the readiness of HE to adopt IoT. A literature review is a well-established method for developing knowledge and interpreting issues under consideration. This study systematically analysed the various research methodologies used to adopt IoT, summarising the content of the studies and highlighting the main factors that may affect IoT adoption in HE.

Findings – The authors examined 95 papers; 35 were investigated and analysed. The literature review and analysis of academic papers revealed the factors influencing the adoption of IoT technology in HE.

Originality/value – By examining the evidence, this study contributes to understanding the context and supplements existing research. It conducts a systematic literature review to assess the impact of the IoT on the educational process, proposes future research directions and presents findings that aid the efficient management of HE resources.

Keywords Internet of things (IoT), Higher education (HE), Smart campus, Smart university, Digital transformation, Smart education, Systematic literature review

Paper type Literature review

Introduction

The Internet of things (IoT) connects physical and intangible items, enabling healthcare, transportation, education and energy use. Throughout history, technology has had a major effect on educational processes. Data, information and technological devices are transforming educational processes, particularly in higher education (HE). European

This article was financially supported by the State Research Agency of the Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/50110 0 011033), via the SPUR project (ref. PID2020-117021GB-I00).

Journal of Applied Research in Higher Education
Vol. 17 No. 1, 2025
pp. 254-273

2050-7003
DOI 10.1108/JARHE-05-2023-0223

research clusters characterise the IoT as a dynamic international network infrastructure based on standards and communication protocol interoperability. These protocols utilise intelligent interfaces and are effortlessly integrated into information networks, sharing user and environment data (Abdel-Basset *et al.*, 2019).

The IoT is defined by the International telecommunication union (ITU) as a global infrastructure for the digital age that enables the integration of physical and virtual objects via the interoperability of communication and information technology (Jamshed *et al.*, 2022). Other researchers provided several alternative definitions. These definitions strongly emphasise the "things" connected by IoT devices. Other definitions of IoT have focused on Internet-related components such as protocols and network technologies. The third group focuses on IoT semantic challenges connected to the storage, search and organisation of massive amounts of data: big data (Wortmann and Flüchter, 2015).

HE institutions can use IoT technologies to improve their processes and activities. According to Matthew *et al.* (2021), HE institutes use IoT, cloud computing, artificial intelligence (AI) and geographic information systems to support teaching, scientific exploration and services. However, AI has also caused a shift in the concept of smart campuses. This has altered university teaching and educational methods, making them more diverse and advanced (Castro Benavides *et al.*, 2020). Augmented reality (AR) and virtual reality (VR) are two of the world's most innovative technological advancements with enormous potential for improving education. The use of AR and VR in education has grown in recent years, opening up a plethora of opportunities to leverage technology-enhanced learning (Al-Ansi *et al.*, 2023).

The IoT and secure blockchains significantly impact education at all levels, focussing on ongoing competent and professional educational processes and distance and online learning. Furthermore, IoT, AI, AR and VR can create virtual simulations that allow students to explore and comprehend advanced ideas in a safe and engaging environment, which is particularly helpful during the COVID-19 pandemic (Al-Ansi and Fatmawati, 2023). To achieve such an environment, governments should support the use of IoT-enabled applications, as proposed by Alam and Parvin (2022), who argued that governments should take the lead in ensuring that students from all socioeconomic backgrounds have the same quality of learning using the available technologies, particularly in the aftermath of the COVID-19 pandemic.

Research gap

IoT can help HE institutions improve their sustainability performance and enhance their research experience by implementing a smart university through easy access to data and campus facilities. Furthermore, it can improve facility operation and management, including energy conservation and environmental sustainability (Phanichsiti *et al.*, 2023; Zeeshan *et al.*, 2022).

Furthermore, the COVID-19 outbreak has pressured educational institutions to transform their teaching-learning methods using advanced technologies. IoT connects people, devices, processes and data, allowing educational stakeholders to transform sensor and portable device data into useful information. Although technological advancements have allowed education to advance quickly, smart technology implementation has challenges that must be addressed further (Adedoyin and Soykan, 2023).

Despite the lack of vision, capability and commitment to implement new technologies effectively, numerous educational institutions have developed specific digital strategies in response to the massive shift in new technologies (Bhana *et al.*, 2023). In this regard, a comprehensive vision of all research within HE institutions is critical to gain an overview of the current state and identify distinguishing characteristics, such as dimensions, actors and implementations during the digital transformation process (Ali *et al.*, 2023).

This study provides an overview of the research through a systematic literature review (SLR) of IoT in HE institutions. It proposes factors and challenges that may be faced during IoT-enabled technology adoption.

Research aim and objectives

Despite numerous studies on IoT in HE, there is a lack of consolidated and coherent perspectives on this subject (Malik *et al.*, 2023; Woithe and Filipec, 2023). Therefore, this study provides an overview of relevant research investigating existing scenarios for deploying IoT and an in-depth look at the advantages of incorporating IoT technologies into HE. This study organises the existing IoT in educational scenarios and provides a framework for additional analysis and discussion that researchers and practitioners can use to develop an efficient research path.

Therefore, the research objectives are as follows:

(1) Examine the current evidence in the investigated field,

(2) Understand and supplement the research context,

(3) Evaluate the impact of IoT on the educational process, suggest future research directions and present research findings that may aid in efficiently managing HE resources.

Research questions

This was the initial phase of systematic mapping (Yli-Huumo *et al.*, 2016). This project examines the impact of IoT on educational processes to improve the management of HE resources. Therefore, the research questions were as follows:

RQ1. How did IoT-based research projects contribute to the development of new knowledge and solutions in the field of HE?

Through this question, this study attempts to identify and assess the common trends regarding IoT technology through a thorough study of the available publications to the year of publication.

RQ2. What are the main factors affecting IoT adoption in HE institutions?

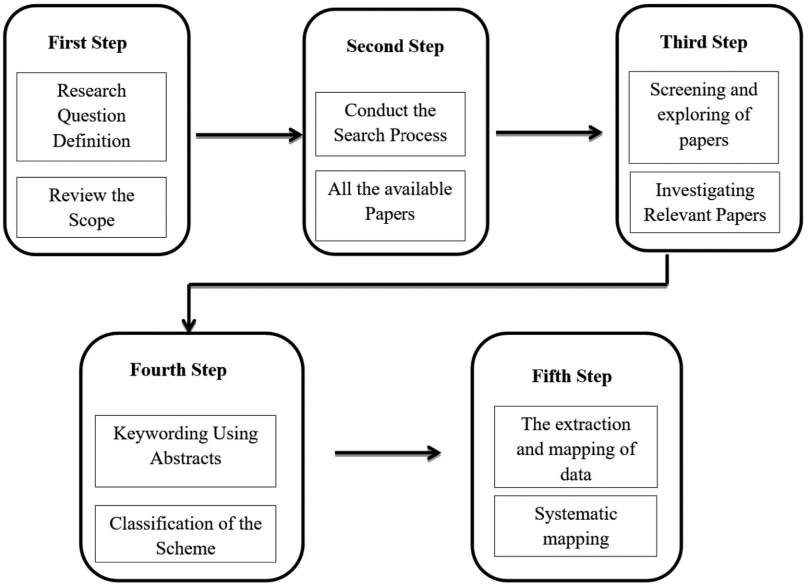
This question attempts to identify the main factors that may influence the use of IoT in enhancing the efficiency of HE processes by analysing available research papers, identifying the variables included in them, and their importance.

RQ3. How did HE institutions in different countries approach the advantages and challenges of IoT adoption?

Through this question, this study attempts to identify the pros and cons by exploring the available research and identifying the limitations and future possibilities that may help offer a more interactive and efficient educational process in HE institutions.

Research methodology

The SLR aims to answer research questions by collecting and examining a comprehensive list of published studies on the research topic (Cronin *et al.*, 2008). Similarly, Agbo *et al.* (2019) introduced the goal of systematic mapping: obtaining an overview of the research context and supplementing it with evidence on specific topics. In this study, an SLR was conducted to assess the effect of IoT on HE to manage HE resources effectively. The systematic mapping process consisted of five steps (Yli-Huumo *et al.*, 2016), as shown in Figure 1.



Source(s): Author's own creation/work

Figure 1.
Research protocol

Conducting the search

The second stage of the mapping study searched for all scientific papers on the research topic. Before beginning the research process, the researcher must define the protocol (Yli-Huumo *et al.*, 2016). The data for this study were gathered from various related scientific databases, such as papers published at conferences, workshops, symposiums, books and journals. IEEE, Web of Science, Academia, Springer, ResearchGate, Wiley, Elsevier and Emerald Insight are among the databases used in this study. The following keywords were identified: IoT, HE, HE-institutes and efficiency of the HE process.

Screening of relevant papers

This step begins after collecting the scientific database and consists of two major phases. First, the relevance of the collected papers is checked based on their titles, ignoring those unrelated to the identified keywords. Second, the relevance of the selected papers is determined by reading the abstracts, introduction and conclusion to determine whether the papers met our exclusion criteria (Agbo *et al.*, 2019). Overall, 95 articles were collected, of which 60 were excluded, and 35 were chosen. As shown in Figure 2, a SLR was conducted following the PRISMA flow.

Keywording based on the abstract

This step represents a more advanced stage in selecting suitable articles. This step comprises two phases. The first phase involves reading abstracts, keywords and concepts. The second phase was to develop a better understanding based on the keywords collected from the selected papers. Subsequently, all the selected papers were explored precisely to start the next step, which was their analysis (Agbo *et al.*, 2019). The keywords and search operators used were ("IOT" OR "Internet of Things") AND ("smart campus" OR "smart university") AND ("Higher Education" OR "HE") AND ("Digital Transformation" OR "Smart Education").

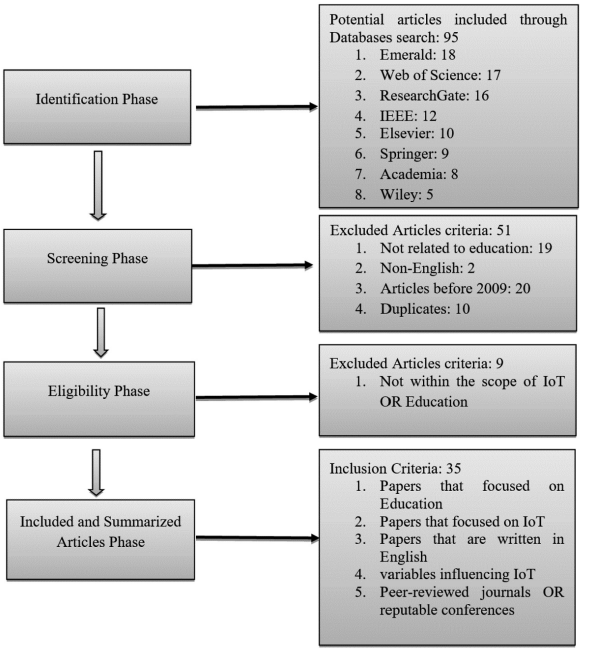


Figure 2.
Research PRISMA flow diagram

Source(s): Author's own creation/work

Data extraction and mapping process

This step involved collecting the information required to answer the research questions. The collected information included documents (article, book and journal), years and subject areas of the collected documents, identified for 35 articles.

Type of documents

This section presents the types and percentages of articles. There were only two articles: journals and conferences, where journals represent 81.82% and conferences represent 18.18% (see Figure 3).

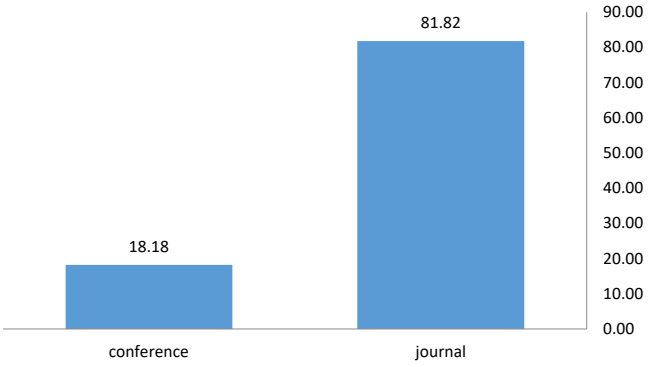


Figure 3.
Type of documents

Source(s): Author's own creation/work

Documents by year

This section shows the number of articles collected for 2009–2021. The maximum number was in 2019 with eight articles, whereas the minimum was in 2011, 2012 and 2015 with only one article (see Figure 4).

Documents by subject area

This section represents the documents according to the subject area, including the educational sector, HE sector, IoT technologies, healthcare sector, tourism and hospitality sector, food retail supply chain, and retail firms. The highest percentage was for the HE sector (40.625%), with 13 articles (see Figure 5).

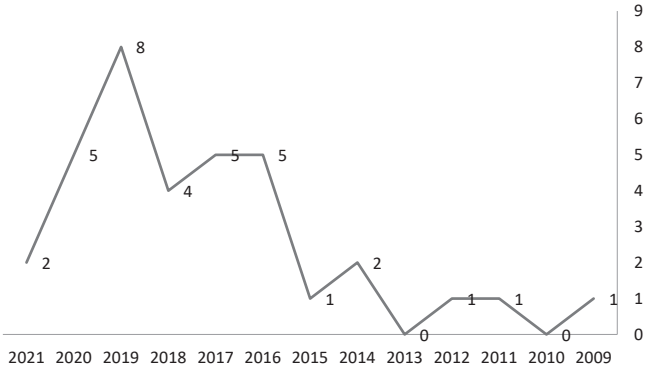


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Figure 4.
Published documents by year

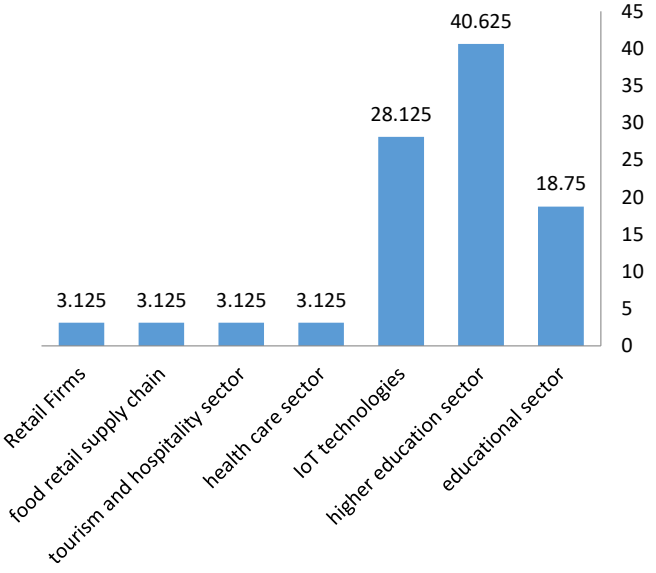

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Figure 5.
Documents by subject area

Article overview

This section summarises prior research in this area. HE institutions were at the core of the search criteria because they were the primary source for the future of any country, and this could only be achieved through advanced research and development.

The following Table 1 introduces the collected articles, citations, channels through which articles and studies were published, and the impact factor analysis of each channel.

Previous research has explored the relationship between cost, security, trust, perceived usefulness, ease of use and efficiency in HE processes. However, none have investigated their overall relationship and how it may affect HE efficiency (Migliore, 2012). Tout *et al.* (2009) investigated the use of cloud computing in HE institutions as cloud computing has gained popularity in recent years, but concerns about enterprise information security arise. Early adopters must plan and maintain close contact with organisations that set industry standards to ensure a smooth transition using IoT technologies combined with cloud computing technology.

Joo *et al.* (2011) found that learner satisfaction, HE efficiency, perceived presence, perceived utility and simplicity of online learning technologies are related. Perceived usefulness and ease of use are crucial for boosting performance and efficiency in HE. Trust among board trustees is critical for fostering collaborative cultures that foster innovative change, educational performance excellence and efficiency.

Elkaseh *et al.* (2016) investigated the influence of perceived usefulness and ease of use on HE efficiency using a technology acceptance model (TAM). Social networking sites (SNSs) have been widely used to support and enhance educational activities, but some professors are concerned about their impact on teaching and learning processes. Perceived usefulness and simplicity were crucial in assessing students' and instructors' behavioural intentions to accept and use e-learning tools in HE.

Aristovnik *et al.* (2016) evaluated the utility of technological instruments and the efficiency of HE. Blended social learning is a well-established practice of HE, and incorporating information and communication technology into the educational process has resulted in new teaching approaches and strategies. Teachers now have options to make teaching and learning more interesting and participatory, making them more comfortable with technology and smartphones.

Rajesh (2017) claimed that incorporating new information and communication technology tools into teaching and learning processes is crucial for the success of the HE sector. The perceived utility gained from professors' diverse structures and coursework has a beneficial impact on HE. Cloud computing security is a major challenge for educational institutions, as it cannot deal with security issues. To address these challenges, cloud service providers should develop partnerships and focus on common security risks and vulnerabilities.

Kholmuminov and Wright (2017) investigated the financial resources of universities and their implications for educational effectiveness during recent financial crises. They found that education expenditures do not necessarily result in successful long-term student outcomes. Public HE institutions with more undergraduate students are less cost-effective than those with a lower proportion.

Nugroho *et al.* (2018) monitored e-learning or distance learning, that uses information technology to deliver information or knowledge regardless of time or location, allowing students to study at their own pace and more equitably. E-learning can enhance instruction quality, HE efficiency and student performance by improving students' perceptions of an institution's usefulness and simplicity of use. Blended learning, which combines face-to-face classroom instruction with asynchronous online learning using blindfolded learning, has been shown to impact HE efficiency.

Bagheri and Movahed (2016) researched the internet-connected IoT devices technology, showing how it can improve the efficiency of educational business procedures. Keržič *et al.* (2019) demonstrated that IoT allows physical devices, sensors and controls to communicate

Table 1. Chosen articles of the research

Number	Paper name	Citations	Publication channel	Impact factor analysis	Factors found
1	Online University Students' Satisfaction and Persistence: Examining Perceived Level of Presence, Usefulness and Ease of Use as Predictors in a Structural Model	459	Computers and Education	10.88	Teaching Presence, Social Presence, Cognitive Presence, Usefulness/Ease of Use
2	Perceived Ease of Use and Perceived Usefulness of Social Media for e-Learning in Libyan HE: A Structural Equation Modelling Analysis	311	International Journal of Information and Education Technology	3.078	Social Media, Perceived Usefulness, Perceived Ease of Use, Attitude towards Behaviour, Behaviour Intention to Use
3	Exploring Critical Factors of the Perceived Usefulness of Blended Learning for HE Students	42	PLOS one	3.24	Technology Acceptance, E-Teaching, Attitude to Face-to-Face, Perceived Usefulness
4	Systematic Review of Cloud Security Challenges in HE	13	The online journal of Distance Education and e-Learning	1.702	Security and Privacy, Cloud infrastructure, Access Control, Cost, Complexity
5	Determining Factors of Students' Perceived Usefulness of E-Learning in HE	19	International Conference e-Learning	0.3	Perceived Usefulness, E-Learning, Face-to-Face Learning, Structure of Course, Workload
6	The Impact of Perceived Usefulness and Perceived Ease of Use on Student Performance in Mandatory e-Learning Use	8	International Conference on Applied Information Technology and Innovation (ICAITI); IEEE	1.04	Perceived Ease of Use, Perceived Usefulness, Users' Performance
7	Improving IoT Technology Adoption Through Improving Consumer Trust	84	Technologies; MDPI	1.994	Functionality and Reliability, Helpfulness, Ease of Use, Perceived Usefulness, Social Network, Community interest, Product/ Service Security, Perceived Risk, Trust
8	A Unified Perspective on the Factors Influencing Consumer Acceptance of IoT Technology	495	*Asia Pacific Journal of Marketing and Logistics*	2.511	Perceived Ease of Use, Perceived Usefulness, Trust, Social influence, Perceived Enjoyment, Perceived Behavioural Control, Behavioural intention to Use

(*continued*)

Table 1.

Number	Paper name	Citations	Publication channel	Impact factor analysis	Factors found
9	Behavioural Intention to Use IoT Health Device: The Role of Perceived Usefulness, Facilitated Appropriation, Big Five Personality Traits, and Cultural Value Orientations	46	*International Journal of Electrical and Computer Engineering*; SSRN	1.211	Openness, Agreeableness, Extraversion, Conscientiousness, Neuroticism, Facilitated Appropriation, Perceived Usefulness, Behavioural intention
10	Factors Affecting the Adoption of IoT Devices: A Correlational Study	–	Dissertations and Theses; ProQuest	0.57	Perceived Ease of Use, Perceived Usefulness, Adoption Intent (IoT)
11	IoT in HE: A Study on Future Learning	189	IOP Publishing. *Journal of Physics: Conference Series*	8.374	Cloud Computing, instructional Technologies, Mobility Applications, Security and Privacy, Research Computing, Quality and Ethics, Financing, IoT Adoption
12	The Effect of Not Using the IoT in Critical Life Situations in the Health Field and the Effect on Iraqi Profitability	9	Journal of Southwest Jiaotong University, Computer Science; SSRN	0.64	Awareness, Security, Cost, Government Support, professional Behaviour, Collaboration
13	Toward Industry 4.0 with IoT: Optimising Business Processes in an Evolving Manufacturing Factory	35	Frontiers in ICT	0.427	Complexity, Setup Delays, Traceability, Blockchain introduction, introducing IoT
14	IoT as Key Enabler for Efficient Business Processes	–	SSRN	. . .	Security, Privacy, Complexity, Generating insights, IoT Readiness For innovation
15	The IoT Promoting HE Revolution	82	IEEE Xplore	3.557	Educational Virtual Technology, Education Reform, Changes in Teaching, Change of Learning, Management of Change, Experimental and Practical Change, Changes in Campus, Teaching Resources and Other Changes

(*continued*)

Number	Paper name	Citations	Publication channel	Impact factor analysis	Factors found
16	IoT in the Education Sector: Applications and Challenges	–	Applications of AI for Smart Technology, IGI Global	4.201	Secure Learning Environment, Efficient Resource Tracking, Efficient Access to information, and intellectual Plan Development
17	Role of the IoT in HE	18	International Conference on Advances in Education and Social Sciences	. . .	Integration of Technology, Blended Learning, Communication, Enabling Special Needs People with Disabilities to Work and Be Dependent
18	Review on IoT in enhancing efficiency among HE institutions	6	Journal of Critical Reviews	1.091	Privacy, Security, Accuracy and Efficiency of Committed Errors, Time, Quality
19	The effect of security, privacy, familiarity, and trust on users' attitudes toward the use of IoT-based healthcare: the mediation role of risk perception	76	IEEE Access	3.367	Security, Privacy, Familiarity, Trust in IoT, Risk Perception, Attitude toward Using IoT
20	IoT in Tourism and Hospitality: Opportunities and Challenges	37	Tourism in Southern and Eastern Europe; Academia	0.027	Scalability, Self-Organising, Data Volumes, Data interpretation, interoperability, Automatic Discovery, Software Complexity, Security and Privacy, Fault tolerance, Power Supply
21	Predictable Influence of IoT in the HE	97	*International Journal of Information and Education Technology; Academia*	0.42	Engagement, Creativity, E-Learning, Self-Learning, Research Opportunity, Collaboration, Hyper Connectivity, Scalability, Performance, Big Data, Cognitive Aspect, Learning Efficiency
22	The Effect of the IoT on Education Business Model	157	International Conference on Signal-Image Technology and internet-Based Systems (SITIS); IEEE	0.00	Cost, Time, Safety, Personalised Learning, Engagement and Collaboration, Value Propositions

(*continued*)

Table 1.

Table 1.

Number	Paper name	Citations	Publication channel	Impact factor analysis	Factors found
23	The Impact of IoT in HE	57	Scientific Bulletin-Economic Sciences		IoT Security, IoT Analytics, IoT Devices, IoT Processors, IoT Operating Systems, IoT Platforms
24	IoT and Quality of HE in Kenya	2	ResearchGate		Cloud Computing, Security and Privacy, Reliable Wi-Fi Connection, Financing
25	IoT and Business Processes Redesign in Seaports	111	*Business Process Management Journal*; Emerald	2.121	Efficiency, Networked, Customisation, Ubiquitous and Pervasive Presence, Improving Productivity and Cost Savings
26	Modelling the IoT Adoption Barriers in Food Retail Supply Chains	160	*Journal of Retailing and Consumer Services;* Elsevier	7.77	Connections, Announcement, Business Models and Processes, Security, Extensibility, Scalability, interoperability
27	The Effect of "Internet of Things" on Supply Chain Integration and Performance: An Organisational Capability Perspective	85	*Australasian Journal of Information Systems*	1.147	IoT Capability, Supplier integration, internal integration, Customer integration, Supply Chain Performance, Organisational Performance
28	Cloud Computing and its Security in HE	64	Proceedings of the ISECON Conference	0.07	Security, Performance and Availability, integration and Customizability, Cost
29	IoT in Smart Education Environment: Supportive Framework in the Decision-Making Process	183	Concurrency and Computation: Practice and Experience; Wiley	1.447	Interconnectivity, Protection of Privacy and Semantic Uniformity, Heterogeneity, Dynamic Change, Enormous Scale, Safety, Connectivity
30	5G IoT: A Survey	1,862	Information Systems Frontiers; Springer	5.837	Cost, Size, Resource, and Energy Consumption, Deployment, Heterogeneity, Communication, Network, integration, Security and Privacy
31	E-Learning Material Development Framework Supporting 360VR Images/ Videos Based on Linked Data for IoT Security Education	10	Emerging Internet, Data and Web Technologies		Security, IoT Threat

(*continued*)

Number	Paper name	Citations	Publication channel	Impact factor analysis	Factors found
32	Big Data, the IoT, and the Revised Knowledge Pyramid	80	ACM	1.686	Knowledge Management, Analytics, Big Data, Business intelligence initiative, Customer intelligence initiative, Creation and Adoption of IoT Technology
33	Emerging Technologies to Smart Education	6	*International Journal of Computer Trends and Technology*	5.21	Effective Education, Cost Efficiency, The Use of Different Technologies and Its Effect on The Education Process
34	Sensing as a Service Model for Smart Cities Supported by the IoT	1,098	Transactions on Emerging TelecommunicationsTechnologies	1.594	Standardisation, Accuracy, Architectural Designs, Sensor Configuration, Data Filtering, Processing and Storage, infrastructure and Energy Consumption, innovation, Entrepreneurship and Entry Barriers, Sustainability, Licencing, Business Practices, Credibility, Trust, Social Acceptance, Change Management, Awareness Security and Privacy, Safety, Accessibility, Usability and Legal Terms
35	Blockchain and IoT in HE	27	*Universal Journal of Educational Research*	0.214	Building Trust, Minifying the Possibility of Accidents, Minimising Costs, Minimising Time, Security and Privacy

Table 1.

over the internet, transforming learning from knowledge transfer to active collaborative self-directed learning. Researchers have identified seven strategies, tools and technologies: social media, enabling, consumer, Internet, digital, learning and visualisation technologies.

Abbasy and Quesada (2017) demonstrated that the Internet of things (IoT) has significantly impacted the education and HE sector, offering opportunities for hyperconnectivity, cooperation and research. According to Banica *et al.* (2017), IoT technology has transformed traditional educational systems into more adaptive and responsive to dynamic changes, enabling students to learn quickly and effectively through problem-solving, personal management and video and gamification-based learning approaches. However, educators need to integrate these new teaching and learning techniques into their practices, encouraging collaboration, active learning and increased communication between instructors and students.

According to Pervez *et al.* (2018), recent technological developments have made traditional classroom instruction less effective and appealing to students in the twenty-first century. IoT can improve the efficiency of college and university education by making students feel more at ease and engaged, improving exam results and providing opportunities for professional growth. Teachers also benefit from IoT technology, as they can find resources for lectures, submit online assessments with automatic corrections and hold online meetings with parents.

Belli *et al.* (2019) found that recent advances in research have opened new possibilities for industrial applications of the IoT. According to experts, IoT technologies are adopted in two primary stages: digitalising quality control processes and digitising production planning. This leads to decreased costs, improved product quality and efficient supply chain solutions. IoT can also automate administrative tasks and improve the quality of the entire process.

Mishra *et al.* (2020) highlight the positive impact of IoT on educational institutions, highlighting its potential to enhance student safety, provide communication channels and support physically or cognitively impaired students. The study emphasises the positive effects of IoT on the administrative framework, automating tasks and improving the quality of the educational process, rather than focussing on its negative effects.

Alam and Khan (2021) studied the impact of IoT usage on business process efficiency, finding that IoT positively influences corporate processes by offering better services, upgrading manufacturing processes, increasing productivity, obtaining more profit and improving product quality. However, security concerns, lack of confidence and lack of ability to provide insights remain barriers to IoT growth.

As a result, smart education that relies on IoT has gained interest due to the rapid rise of technologies such as smart devices, cloud computing, ICTs, fog computing, machine learning and big data analytics as IoT focuses on improving lifelong learning skills and allowing students to leverage distance education.

Findings

IoT is complex and diverse and encompasses a wide range of technologies. AI, big data, cloud computing, blockchain, VR and AR are key smart technologies that should aid the IoT in the digital transformation of HE institutions (Alhasan *et al.*, 2023).

Moreover, the COVID-19 pandemic has dramatically changed learning environments, affecting most HE stakeholders, including students, teachers, families and decision-makers (Al-Ansi, 2022). COVID-19 has resulted in different educational environments, including traditional, online, blended, and distance learning. IoT has aided in the transition of education using new trends in online and interactive learning environments since the beginning of the COVID-19 pandemic (Sultana and Tamanna, 2022).

IoT has aided in integrating new trends in education, particularly during the COVID-19 pandemic, to achieve best practices and improve the learning-teaching process. In blended

learning (Al-Ansi, 2021), for example, IoT-enabled applications were used to reduce coronavirus spread by monitoring students' temperatures, alerting anyone if they had a fever and attending without any human intervention (Qiao *et al.*, 2021). Furthermore, AR and VR aid students by allowing them to explore and interact with real-world environments without being physically present (Al-Ansi *et al.*, 2023).

Variables affecting IoT adoption

After reviewing the articles, it was found that IoT had potential in various industries, especially education. AI, big data analytics, blockchain, cloud computing and communication networks are among the main technologies that enable infrastructure, software and platforms to operate together using a common logic to achieve smart campuses (Tout *et al.*, 2009; Tianbo, 2012; Perera *et al.*, 2014; Rajesh, 2017; Aldowah *et al.*, 2017; Abbasy and Quesada, 2017; Jennex, 2017; Pervez *et al.*, 2018; De Vass *et al.*, 2018; Al-Hashimy *et al.*, 2019; Belli *et al.*, 2019; Kulshrestha and Bose, 2019; Hartman, 2020; Letting and Mwikya, 2020; Palanivel, 2020; Alam and Benaida, 2020; Alam and Khan, 2021; Singh and Masilamani, 2021).

Moreover, users who believed IoT-enabled applications were beneficial and easy to use were more likely to have a good attitude toward the technology, increasing their intention to utilise it, boosting their performance and the efficiency of HE processes (AlHogail, 2018; Aristovnik *et al.*, 2016; Elkaseh *et al.*, 2016; Gao and Bai, 2014; Hartman, 2020; Joo *et al.*, 2011; Keržič *et al.*, 2019; Nugroho *et al.*, 2018; Prayoga and Abraham, 2016).

Even though IoT has many positive aspects, stakeholders have some concerns such as privacy, security and trust issues (Tout *et al.*, 2009; Perera *et al.*, 2014; Rajesh, 2017; Aldowah *et al.*, 2017; Banica *et al.*, 2017; AlHogail, 2018; Li *et al.*, 2018; Al-Hashimy *et al.*, 2019; Alraja *et al.*, 2019; Car *et al.*, 2019; Kamble *et al.*, 2019; Abdel-Basset *et al.*, 2019; Kulshrestha and Bose, 2019; Mishra *et al.*, 2020; Letting and Mwikya, 2020; Alam and Benaida, 2020; Alam and Khan, 2021; Singh and Masilamani, 2021).

Another aspect that hinders the full adoption of IoT technologies is their complex dependencies and energy and environmental issues, where physical environments, such as humidity and high temperatures, can adversely affect the performance of IoT devices. Operations must enable autonomous detection, prevention and improvement of issues at certain scales without human intervention (Abdel-Basset *et al.*, 2019; Alam and Khan, 2021; Belli *et al.*, 2019; Car *et al.*, 2019; Li *et al.*, 2018; Perera *et al.*, 2014). Moreover, COVID-19 has impacted the education sector because of partial or complete lockdowns implemented globally between 2019 and 2022. This pandemic has significantly impacted the education sector, as all educational institutions have shifted to online education (Alam, 2021). However, the education sector lacked the teaching experts, digital experts, IoT and resources required for online education. During a pandemic such as COVID-19, the shift from traditional to online education has created many challenges, such as the cost of IoT-enabled applications. This prompted governments to take serious steps to improve the performance of students, teachers and all education sectors during the COVID-19 pandemic and in the event of future pandemics (Alam, 2022).

Furthermore, IoT technology provides a rich and flexible platform for students, teachers, administrators and others to explore, learn and interact with educational systems in a super-intelligent environment; however, the current price of this technology may hinder its application, especially in countries that are not financially ready (Alam and Benaida, 2020; Al-Hashimy *et al.*, 2019; Bagheri and Movahed, 2016; Ferretti and Schiavone, 2016; Li *et al.*, 2018; Palanivel, 2020; Rajesh, 2017; Tout *et al.*, 2009).

Discussion

The IoT is considered a giant sensor that accrues voluminous data over time, evolving from raw data to information to knowledge and then uses this knowledge to make successful

decisions (Jennex, 2017). A smart university can utilise smart devices that communicate via IoT to send and receive data and instructions for the best available resources (Abdel-Basset *et al.*, 2019). HE institutions should provide the most personalised learning experiences possible by incorporating IoT technologies, cloud computing, geographic information systems, AR and VR (Alqahtani and AlNajdi, 2023).

Utilising IoT in HE institutions and learning centres helps them by enabling better learning programs, tracking critical resources, improving information access and constructing secure campuses. IoT is a potentially revolutionary classroom and laboratory management concept that uses established tools (Chopra and Arora, 2023; Palanivel, 2020).

Additionally, IoT can aid in various aspects of HE processes, such as smart digital boards, interactive learning tools, educational applications for mobile devices and tablets, electronic books and other learning sources, such as online document participation; it can also facilitate communication; wireless door locks can aid in efficiently managing classrooms and laboratories; and advanced security measures that allow only authorised individuals to enter (Abdel-Basset *et al.*, 2019).

Therefore, IoT facilitates process monitoring and decision-making by producing, collecting and processing data in real-time to resolve issues efficiently (Teng *et al.*, 2023). Consequently, implementing an IoT framework in HE assists stakeholders in making efficient and secure integration and communication decisions. However, security concerns may arise when implementing IoT technology, addressed by connecting items via blockchain technology, thereby enabling legitimate contact between all stakeholders. Indeed, incorporating blockchain technology into the system's communication framework may provide participants in the connected IoT framework with a reliable, secure and efficient medium of exchange (Alam and Benaida, 2020).

In summary, the IoT is the process of connecting objects and devices to the internet to retrieve real-time information at any time and from any location (Louis and Dunston, 2018; Perera *et al.*, 2014), which can be advantageous in HE institutions, for example, students can interact with real-world objects to promote and improve the learning process (Okada *et al.*, 2019). However, incorporating objects into the educational process requires further research, as previous studies have primarily focused on network connectivity, protocols and security (Kulshrestha and Bose, 2019).

Implications and future work

IoT, cloud computing, Blockchain, AI, VR and AR significantly impact teaching-learning. In the future, the classroom is expected to become a hyper-immersive experience that caters to an experiential learning environment through a purely digital ecosystem, fostering teaching and learning that closely resembles in-person interaction (Al-Ansi *et al.*, 2023).

Moreover, the COVID-19 pandemic has altered how individuals learn and work. Because of social distancing and other safety protocols, businesses and educational institutions must quickly change and find new ways to keep things running smoothly. AR and VR technologies have emerged as powerful tools for staying connected and continuing education because they can enable remote learning. Students can explore and interact with their surroundings more immersively through IoT-enabled applications using VR and AR technologies without being physically present in the classroom.

Furthermore, according to Alam and Parvin (2021), online education is more active than face-to-face education because online students perform better across all educational domains and can be efficiently managed through IoT-enabled applications, particularly during the COVID-19 pandemic. Additionally, according to Alam and Asimiran (2021), a system should not be prevented from delivering sustainable HE programmes, courses or subjects under any circumstances.

Furthermore, no empirical research has been conducted on how IoT applications affect student learning outcomes. Therefore, academics have many opportunities to investigate the factors influencing the deployment of IoT applications in education in general and developing countries in particular.

However, more extensive research should be conducted to identify better ways to deliver sustainable HE programmes, particularly in underdeveloped and developing countries. Further research should concentrate on increasing the efficiency of IoT-enabled processes and technologies while reducing resource utilisation and energy consumption.

Conclusion

This study aimed to investigate how factors influencing IoT usage affect the HE processes. Cost, security, trust, perceived usefulness and perceived ease of use were found to impact the effectiveness of the HE process. To identify this research gap, we conducted a comprehensive literature review that focused on collecting and analysing previous studies on relevant relationships.

A comprehensive mapping procedure was used to collect data from 35 papers. Several studies have suggested that establishing IoT-based learning environments can aid in developing a new paradigm for learning processes in HE institutions, thereby improving learning and teaching processes. However, these efforts were isolated and incomplete, as the variables discovered were not investigated in a single study, particularly in developing countries.

HE is considered a potential candidate for the implementation of IoT applications. The primary goal of this research is to provide a more comprehensive view of the use of IoT applications in HE institutions and to investigate the factors that drive IoT technology adoption and its impact on the efficiency of HE processes.

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