Received 30 January 2023
Revised 13 July 2023
Accepted 21 July 2023

Adoption of the Internet of Things in higher education: opportunities and challenges

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Abstract

Purpose – The purpose of this study is to determine the characteristics of the studies in terms of country, participant profile and methodology, as well as to determine what the Internet of Things (IoT) is currently contributing to higher education.

Design/methodology/approach – The study was developed following the methodology supported by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and the PICOS strategy, retrieving scientific literature from Web of Science, Scopus, ERIC and Google Scholar. Of the 237 studies that the search yielded, 11 were included.

Findings – The results showed that among the opportunities offered by IoT is that it not only brings the introduction of information and communication technology into the classroom, but also enhances student interest, thus, improving the quality of teaching in higher education. On the other hand, one of the challenges it faces is the attitude of teachers towards its adoption, as well as the level of digital competence of teachers.

Originality/value – This study presents how higher education institutions are including the IoT in their educational activities. The IoT refers to a network of digital interconnectivity between devices, people and the internet itself that enables the exchange of data between them, allowing key information about the use and performance of devices and objects to be captured to detect patterns, make recommendations, improve efficiency and create better user experiences.

Keywords Internet of Things, Higher education, Opportunities, Challenges

Paper type Literature review

Funding: This publication is part of the project I + D+i, PID2019-108230RB-I00, financiado por MCIN/ AEI/10.13039/501100011033.

Disclosure statement: The authors report there are no competing interests to declare.

Conflicts of interest: The authors declare no conflict of interest.

1. Introduction

Today many resources of everyday life are connected to the internet. While this may seem a bold statement, one must consider the impact that the internet has had on humanity in general and more specifically on education, communication and science. Without a doubt, the internet is clearly one of the most important and powerful creations in all human history. The internet revolution has led to the interconnection between people through applications on smart devices, email, social networks etc. We are now in the era of interconnection with things or objects, to create and promote a fully informed and comfortable environment for better decision-making and quality-of-life.

The so-called Internet of Things (hereinafter referred to as IoT) represents the next evolution of the internet, which will be a huge leap in its ability to gather, analyse and distribute data that we can turn into information, knowledge and ultimately wisdom. Hence, we are talking about an immensely important term, as it manages to integrate four pillars:

(1) people;
(2) processes;
(3) data; and
(4) things.

The integration of these pillars is gradually transforming the traditional way in which educational, research, management and other processes and activities are conceived and carried out.

Transformations in Higher Education Institutions are generating increasingly intelligent environments, according to Cespedes (2019). However, risks and opportunities also arise in the context of higher education with the advent of the IoT. This technology is experiencing rapid growth, with the proliferation of connected devices expected to multiply in the coming years. These devices, many of which are commonly used in universities, have the potential to create immersive and connected educational environments, as well as fostering greater sustainability and resource efficiency (Dave, 2011).

Academic institutions are currently including IoT in their educational activities, however, there are still few review studies available that do a comprehensive sweep on the acceptance and adoption of IoT in higher education. Therefore, this research was developed with the aim of filling this research gap as well as exploring existing scenarios for their inclusion and implementation in higher education through a systematic review of the literature. The results obtained will be useful for use by researchers or practitioners in higher education in the future. To meet the objectives, this study seeks to answer three research questions:

RQ1. What is the overall research status of studies addressing IoT in higher education?

RQ2. What is the contribution of the adoption of the IoT in higher education?

RQ3. What are the challenges of incorporating IoT in higher education?

2. Conceptualisation

In 1999, a British entrepreneur, Kevin Ashton, during a presentation at Proctor and Gramble first introduced the concept of the IoT by describing a solution that involved integrating radio frequency identification (RFID) tags into the company's supply chain (McFarlane *et al.*, 2003). The rationale for this idea was that, at the time, most of the information fed into systems or computers came from a human, with the disadvantages of speed, time availability, susceptibility to errors, among others (Ashton, 2009). However, since the term was first coined, the definition has evolved over the years.

The basic idea of IoT is a new model based on RFID, sensors and actuators that can interact with each other (Parashar *et al.*, 2016), i.e. it is the next step in the evolution of smart objects. In 2008, the term was coined to refer to:

> Objects that have a virtual identity and personality, and that function in smart spaces using intelligent interfaces to connect and communicate within a social context, the user and their environment (European Commission, 2008).

In recent years, according to figures, the number of devices connected to the internet worldwide will increase from 20 billion in 2020 to 75 billion in 2025, excluding computers, mobile phones and tablets (Review42,42, 2022). As for the type of devices, they can be anything from sensors to everyday objects such as your fridge or clothes. Anything can be connected to the internet and interact without the need for human intervention, the goal is, therefore, machine-to-machine (M2M) interaction, or what is known as M2M interaction or devices. M2M devices are devices that are designed to communicate and share information directly with each other, without the need for human intervention. These devices use communication technologies, such as wireless networks, to exchange data and perform actions in an automated way. In the context of the IoT, M2M devices are a fundamental part. They enable the interconnection of everyday objects with communication capabilities, such as sensors, meters, cameras, appliances, vehicles and other devices.

The arrival of the IoT represents a radical change in people's quality-of-life, providing applications and services that will allow us to integrate an improvement in the relationship between humans and devices in our daily lives. In other words, the IoT will make our daily lives easier by incorporating what are known as smart objects or SOs (Smart Objects) through devices connected to the IP network (Dave, 2011).

This refers to a network of digital interconnection between devices, people and the internet itself that enables the exchange of data between them, allowing key information about the use and performance of devices and objects to be captured to detect patterns, make recommendations, improve efficiency and create better experiences for users (Cespedes, 2019).

Authors such as Mora González (2015) establish three basic elements that interact with each other in the IoT:

(1) The hardware, such as sensors, actuators (devices that control the systems) and other communication devices housed in the objects;

(2) The middleware platform, which is the software that allows the exchange of information between applications, as well as the computational tools that allow data analysis; and

(3) The tools that easily allow the visualisation and interpretation of information and that must be designed to be used by different applications and devices.

As more people have access to a global information and communication infrastructure, the internet is becoming the global platform to enable society or smart objects to communicate and coordinate with each other. Hence, the history of IoT is still undeveloped, and is still being written every day. In fact, IoT is in full swing, with new, smarter, more innovative devices, new protocols, new access technologies, etc. converging with advances in other technologies such as cloud computing, big data and artificial intelligence, enriching and giving more and more opportunities for growth to the IoT universe.

3. IoT and higher education

Multiple factors are involved in the proliferation of IoT, such Everlet and Pastor, 2013; Taravilla, 2013):

- The popularisation of free hardware boards and the computing power of reduced chips;
- Cheaper sensors and tags for objects; improved communications and easily accessible wireless internet;
- The proliferation of new personal devices with associated intelligence;
- IoT platforms and the abundance of shared information; and
- Finally, the connection possibilities of IPv6, 4G, 5G and internet.

With the combination of these factors, we have the possibility of incorporating IoT into our lives in general and into education. In this sense, the full development of technology has had a disruptive influence on higher education institutions, shifting the paradigm from mere knowledge transfer to a self-directed and active collaborative model. Furthermore, we can say that the use of IoT and its technological devices are allies in the educational process (Abdel-Basset *et al.*, 2019). The use of IoT technology is promoting a gradual disruption in the teaching and learning process. The use of the IoT in higher education has contributed to an increase in the quality-of-learning, flexibility for the actors in the educational process, significant cost savings compared to conventional education, effectiveness, efficiency in the teaching-learning processes, among many others, which ensure a level of primacy in educational institutions that are willing to implement these tools in their educational centres (Veintimilla *et al.*, 2018).

This influence has caused universities to rethink their current models of teaching and learning and to adapt their teaching models to the most innovative and modern techniques. In this way, higher education has gradually been transformed within the IoT universe, where different educational parameters can be found using Big Data, augmented reality and/or cloud computing techniques on this platform, among others. These technologies have created a new link between educational environments and students to provide useful information and new knowledge. The application of IoT in education can be found mainly in the following aspects:

- To control access to classrooms;
- To improve teaching and learning;
- To monitor students' health; and
- To know the ecosystem in real time and/or to manage the institution.

The above and a further preliminary review of the literature could lead one to think that IoT technologies have impacted Higher Education Institutions, in the first instance, in the preparation for the development of IoT applications; and, in the second instance, in the use of this technology to support teaching-learning processes (Villegas *et al.*, 2019). However, these are not the only relationships between IoT technologies and higher education institutions. IoT also highlights the need to train their teachers and staff in the use of such a system (Aeris, 2019), i.e. IoT as a support for teacher training, through personal and smart technologies.

On the one hand, authors such as Agarwal and Pati (2016) argue that IoT brings great challenges and opportunities for higher education, such as the development of ubiquitous computing (Martín *et al.*, 2011), cloud computing (Corrales Compagnucci, 2019) and the large amount of information and analysis provided that help to advance the core values of teaching and the quality of research. On the one hand, this pedagogical and innovative trend in Higher Education Institutions is reflected, among others, in aspects such as (Gayá, 2017): teaching and learning strategies (smart learning); highly technological services (smart campus); smart classrooms that facilitate student-teacher interaction (smart classroom) and

the design and development of multimedia content for learning (smart education; Cabrera Cruz and Smith Rueda, 2017); Virtual Reality (VR) and IoT, as an alternative to create a virtual environment for students to carry out their practical work (Fahim *et al.*, 2019).

On the other hand, studies are also being carried out that propose the development of new educational policies or revisions of current ones to help encourage and educate students on the good use of ICT resources, as well as to find out the degree of acceptance of IoT among university teaching staff (Nie, 2013).

Broader studies with the purpose of establishing the relationships between IoT and Higher Education Institutions (Romero-Rodríguez *et al.*, 2020) identified six types of relationships that cover most areas of a university, such as education, campus facilities, resources and technological infrastructure. Of these six relationships, "the management of educational facilities and resources" is the one for which most application cases have been found. In this sense, and with an emphasis on education, we can affirm that the incorporation of IoT devices in education not only supports the teaching-learning process, but also becomes a very powerful tool for classroom management. In this line, the development of IoT in innovative applications in education lies in the following aspects:

- Progressive evaluation of students;
- Integration of current teaching platforms; and
- Development of educational middleware.

In this sense, many authors consider that the trend is towards personalisation of learning, gamification, geolocation and access through tablets, but the implementation of these technologies in areas such as digital literacy and training of both students and teachers remains a challenge (Acosta-Diaz *et al.*, 2018).

4. Method

This systematic review, covering the last five years, aims to analyse and extend what has been studied about IoT adoption in higher education. A systematic review is a rigorous method for systematically collecting, evaluating and synthesising the available evidence on a specific research topic (Page *et al.*, 2016). Thus, due to its importance and value in the generation of reliable knowledge based on the available evidence in the field of study, it has been decided to carry out this systematic review. Unlike other types of studies, sampling in a systematic review does not rely on randomisation to select the studies to be included in the analysis. In a review, a comprehensive database search is used to identify studies that adequately address the research question. These studies will be selected according to pre-defined inclusion and exclusion criteria. This sampling strategy does not guarantee a complete representation of all studies conducted in the field, but seeks to ensure that the most relevant and rigorous studies are included to answer the review's research question. To ensure the quality of the review, the literature search was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement as research protocol (Moher *et al.*, 2014).

4.1 Sources of information

The literature search was conducted in four electronic databases:

(1) Web of Science (WoS);
(2) Scopus;
(3) Education Resources Information Center (ERIC); and
(4) Google Scholar.

These databases were chosen because they include internationally indexed, reliable and high-quality articles. The search date was June 2022.

4.2 Eligibility criteria

To select the most relevant and current papers for this study, different search criteria were established. The axis from which the above criteria were applied is the PICOS strategy:

- Population;
- Phenomenon of interest;
- Context; and
- Study design (Pertegal-Vega *et al.*, 2019).

The population responds to the first criteria of the search delimitation:

- Use of keywords in Spanish and English;
- Temporal limitation to studies published between 2017 and 2021;
- Type of document (scientific article); and
- Language (English and Spanish) and area (Social Sciences).

All the selected documents come from the main international multidisciplinary databases (Web of Science, Scopus, ERIC and Google Scholar). The phenomenon of interest of this review is based on the IoTs in Higher Education, i.e. those proposals that directly address the subject. Next, the context investigated is the university stage. The study design prioritises quantitative and qualitative articles that analyse this field of study.

Inclusion criteria were:

- Studies published between 2017 and 2021;
- Studies published in peer-reviewed journals;
- Articles related to the IoT; and
- Focused on higher education.

On the other hand, the exclusion criteria were duplicate articles and other scientific publications such as systematic or theoretical reviews, books, chapters and conference papers.

4.3 Search strategy

The literature search was carried out by using keywords related to the research topic and the use of two Boolean AND/OR operators, which articulate the relationship between them, thus, ensuring that the most relevant articles were collected. In this sense, the search terms were used using the following equation: ["technology" OR "Information and Communication Technology" OR "ICT"] AND ["IoT" OR "Internet of Things"] AND ["higher education" OR "university" OR "Universities"]. In this sense, it was decided to focus the search on scientific articles published in the last five years (2017–2021) to identify the most recent articles.

The initial search resulted in 237 potentially relevant studies. To ensure the validity of this work and to avoid selection bias, all studies were first carefully read by two article authors. Any divergent assessments were subsequently discussed with the third author of the article. A 100% agreement was reached between the investigators. This review included a total of 11 studies. A flow chart of the literature selection process can be found in Figure 1.

In the first phase, a search of the selected databases identified 237 records. In the second phase, the authors studied the title and abstract of all records, eliminating 222 studies for

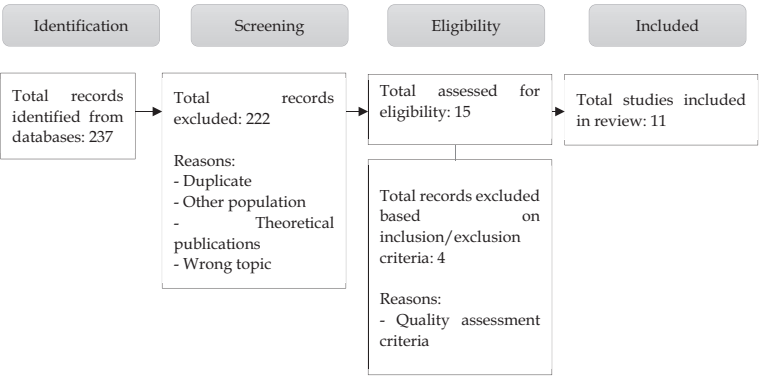

Figure 1.
Flow chart of the review process

Notes: Alt text: Flowchart of the selection process. Identifying the documents chosen in each of the four phases (identification, screening, eligibility and inclusion)
Source: Figure by authors

different reasons: duplicated in another database, theoretical studies, outside the field of education and not focusing on higher education. Thus, for the third phase, 15 studies were pre-selected. This phase focused on reading the full-text articles, and only those that met the inclusion and exclusion criteria were selected, i.e. a total of 11 studies.

4.4 Data extraction and analysis

For data extraction and analysis, a table was first developed to extract the following information from each of the studies included in the review:

- Country;
- Year of publication;
- Methodology; and
- Main results (Table 1).

Studies included in the review are marked with an asterisk (*) in the reference list.

In addition, to understand what the adoption of IoT in higher education contributes to the results of the studies, a system of categories and codes was generated to aid analysis (Table 2). This allowed us to examine the differences and similarities between the studies, as well as to identify the issues addressed in this field of research.

5. Results

Once the studies for the review had been identified, they were analysed to subsequently answer the research questions posed. To have an overview of the studies, they are identified according to their year of publication, place of production and methodology used.

About the years of publication, we can observe that they have been published mainly in the last year. Figure 2 also shows an upward trend in research in this research field.

Among the place of publication, studies produced in Europe ($n = 5$) stand out, with countries such as Romania, Finland, Spain and Bulgaria. Followed by South America ($n = 2$;

Table 1. Description of included studies

Author/s	Year	Country	Method	Findings
Mkrttchian, V., Gamidullaeva, L., Finogeev, A., Chernyshenko, S., *et al.*	2021	Australia	Qualitative	Improving the educational process
Rico-Bautista, D., Maestre-Góngora, G.P., Guerrero, C., Medina-Cárdena, Y. *et al.*	2021	Colombia	Qualitative	Universities need to incorporate smart technologies for quality education
Saeed, M.K., Shah, A.M., Mahmood, K., Ul Hassan, M., Khan, J. and Nawaz, B.	2021	Saudi Arabita	Qualitative	Beneficial for learning
Xie, J. and Yang, Y.	2021	China	Qualitative	Promotes smart teaching and personalised learning
Gilman, E., Tamminen, S., Yasmin, R., Ristimella, E. *et al.*	2020	Finland	Qualitative	Provides rich opportunities to develop smart campuses
Romero-Rodríguez, J.M., Alonso-García, S., Marín-Marín, J.A. and Gómez-García, G.	2020	Spain	Quantitative	The attitude towards the use of IoT by teachers was favourable
Villegas, W., Palacios-Pacheco, X. and Román-Cañizares, M.	2020	Ecuador	Qualitative	Improves the administrative management of the university
Abdel.Basset, M. and Manogaran, G.	2019	Egypt	Qualitative	Increases the quality of the educational process so that students can learn faster
Banica, L., Burtescu, E. and Enescu, F.	2017	Romania	Qualitative	Improves teaching and learning as well as creates a "smart university" model
Kiryakova, G., Yodanova, L. and Angelova, N.	2017	Bulgaria	Qualitative	Creation of a new learning environment and new possibilities in higher education
Abbasy, M.B. and Quesada, E.V.	2017	Costa Rica	Quantitative	Transforms the education system into a more flexible and efficient one such as E-learning

Source: Table by authors

Colombia and Ecuador) and Asia ($n = 2$; China, Saudi Arabia). To a lesser extent, Africa ($n = 1$; Egypt) and Oceania ($n = 1$; Australia) stand out (Table 3).

Finally, looking at the methodology used in the 11 studies included in the review, we can highlight that most of the studies carried out in this field of research are mainly qualitative studies with 81.82% of the studies ($n = 9$), compared to 18.18% of the studies that used a quantitative methodology ($n = 2$).

Table 2.
Category system of IoT adoption in higher education

Categories	Codes	Description
(1) Opportunities	1.1	Improving the educational experience
	1.2	Security management system
	1.3	Energy efficiency
	1.4	Work efficiency
	1.5	Global connectivity
(2) Challenges	2.1	Privacy
	2.2	Training
	2.3	Financial aspects

Source: Table by authors

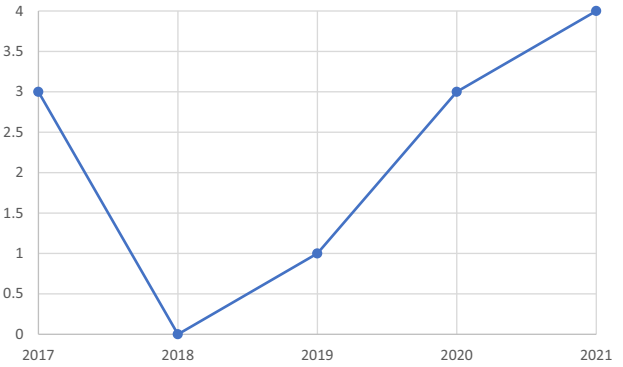

Figure 2.
Production by year of publication

Notes: Alt Text: Distribution of articles by year of publication: three studies in 2017, zero studies in 2018, one study in 2019, three studies in 2020 and four studies in 2021
Source: Figure by authors

Table 3.
Percentage of publication by place of production

Continent	Percentage
Asia	18.18
South America	18.18
Africa	9.09
Europe	45.45
Oceania	9.09

Source: Table by authors

When analysing studies related to IoT adoption in higher education, we were able to identify two emerging dimensions: IoT opportunities and IoT challenges in higher education. These dimensions are explained in more detail below, to understand what the main benefits and challenges are provided by the insertion of IoT in universities (Table 4).

The studies, once they were read, were categorised according to code labels (Table 4).

The research conducted so far highlights that the incorporation of the IoT system generates opportunities and challenges in higher education, which are collected below:

5.1 Internet of Things opportunities in higher education

5.1.1 Enhancing the educational experience. An important aspect of IoT adoption in the university environment is to offer an improvement in the teaching and learning process (Saeed *et al.*, 2021), delivering more enriching learning experiences by obtaining real-time feedback on student performance (Mkrttchian *et al.*, 2021; Rico-Bautista *et al.*, 2021). Therefore, the introduction of IoT not only brings the introduction of ICT in the classroom such as e-books, tablets, sensors and augmented reality, but also enhances students' interest and understanding, thus, improving the quality of teaching in higher education (Abdel-Basset *et al.*, 2019).

5.1.2 Security management system. With the use of sensors and the IoTs, it is possible to manage in a more secure way, access to spaces such as institutions, classrooms or laboratories, student access can be tracked, but at the same time a personalised control and record of student attendance is obtained (Villegas *et al.*, 2019).

5.1.3 Energy efficiency. Using specialised sensors, lighting or heating can be programmed, which improves the energy efficiency of the building and reduces energy waste, leading to cost savings. Likewise, sensors can be put in place to detect the presence of students or programmed to automatically switch off when a classroom is empty, thus, reducing CO2 emissions (Gilman *et al.*, 2020).

5.1.4 Work efficiency. IoT-connected devices also improve speed and save time in carrying out some routine classroom activities such as tracking students (Kiryakova *et al.*, 2017), promoting smart teaching and a smart university campus (Xie and Yang, 2021; Gilman *et al.*, 2020; Banica *et al.*, 2017), while keeping costs under control. Similarly, IoT removes the limitation of physical persons and broadens access to any educational resource, both to teachers and students, anywhere facilitating accessibility to university education

	Categories							
References	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3
Mkrttchian *et al.*	x		x		x			
Rico-Bautista *et al.*	x		x	x	x			
Saeed *et al.*	x		x					
Xie *et al.*	x	x	x	x	x			
Gilman *et al.*		x			x	x		x
Romero-Rodríguez *et al.*	x	x	x				x	
Villegas *et al.*		x		x				
Abdel-Basset *et al.*	x			x	x		x	
Banica *et al.*								x
Kiryakova *et al.*	x	x					x	
Abbasy *et al.*	x	x			x	x	x	

Source: Table by authors

Table 4. Analysis of the contents of the studies

(Abbasy and Quesada, 2017), as well as the management of the educational institution (Kiryakova *et al.*, 2017; Villegas *et al.*, 2019).

5.1.5 Global connectedness. One of the most important outcomes of IoT is the enormous amount of data generated from devices connected to the internet. Thanks to this, students and teachers can access a large storage of data and research from all over the world in real time.

5.2 Challenges of Internet of Things in higher education

Despite the many advantages, the adoption of IoT also poses certain challenges for higher education institutions. Among them, we can mainly find those related to security, economic costs, as well as teacher training.

5.2.1 Privacy. Mainly, the privacy and data protection risks posed using IoT are highlighted (Gilman *et al.*, 2020). Data security and privacy is a major challenge of IoT implementation (Georgescu and Popescu, 2015). Protecting access to data also depends on the users.

5.2.2 Training. In relation to faculty, it has been shown that to employ IoT in higher education, both the acceptance and attitude of faculty for its adoption, as well as their level of digital competence (Romero-Rodríguez *et al.*, 2020), is fundamental. Therefore, the need to train faculty in the use of such a system is a challenge (Kiryakova *et al.*, 2017).

5.2.3 Financial. The implementation of an educational IoT system presents other challenges, such as the costs of the various devices. This occurs mainly at the time of acquiring the necessary equipment, but in the long term this technology reduces costs (Abbasy and Quesada, 2017).

6. Discussion

Today, IoT is a reality and is in a stage of strong development and expansion. There are more and more devices that make it possible to use this technology at low cost and high speeds. In the field of education, such technology associated with IoT enables a new education. Thus, the aim of this review was to examine what the adoption of IoT can bring to higher education and its students. In analysing the different studies identified, the authors analysed the studies according to the year of publication, the country of production, the methodology used, as well as the main findings. In this way, it has been possible to answer three research question posed.

6.1 What is the general state of research on Internet of Things research in higher education?

Academic research on IoS technology applied to higher education has a great impact in different countries around the world that are betting on digital interconnection. However, the knowledge about the use of IoS in education is still blurred, due to the scarce number of relevant studies in the scientific literature on this field of research. Despite the small number of studies, a positive trend in scientific output has been observed in the last five years, which may be due to the rapid advancement of internet-connected or IoT-based devices in recent years (Khanna and Kaur, 2019). It is also interesting to note that most of the studies included in the review are mainly qualitative in their approach. This means that the studies use this methodology to understand complex phenomena and explore perspectives and experiences of a particular topic.

6.2 What is the contribution of the adoption of the Internet of Things in higher education?

Technologies are advancing at a rapid pace, causing educational institutions to challenge themselves to implement new smart devices in the classroom or institution. It should be

noted that, nowadays, with the diversity of smart devices and access to the internet, their application is much more common than in the past (Márquez Díaz, 2017). In particular, the inclusion of IoT in university education is bringing about a change in the way we understand education by creating a smart environment to support the teaching-learning process and improve the quality of education. The inclusion of IoT in university education has the potential to improve the quality of education for several reasons:

- Access to information and resources: IoT technology enables instant access to a wide range of educational information and resources. Students can access online learning materials, research and explore concepts in greater depth, and access resources in real time, enriching their educational experience.

In this sense, the use of IoT offers new opportunities (remote access to knowledge, flexible learning, online collaboration and participation, enriched learning experiences, personalised feedback, etc.) to students and options for accessing information and knowledge in higher education, where distance is not an impediment (Hermosa, 2015):

- Personalisation of learning: IoT devices can collect data on individual student progress and performance, enabling greater personalisation of learning. Teachers can use this information to adapt teaching strategies and provide targeted feedback, meeting individual student needs and promoting more effective learning.
- Collaborative and participatory learning: IoT facilitates collaboration and interaction between students and teachers. Connected devices enable real-time communication and exchange of ideas, fostering collaborative learning and the active participation of students in the educational process.
- Smart learning environments: The integration of IoT in university classrooms enables the creation of smart learning environments. Connected devices and sensors can monitor environmental variables, such as lighting, temperature and noise level and to optimise learning conditions. In addition, smart building management systems can facilitate efficient scheduling of classrooms and resources, improving the efficiency and comfort of the learning environment. The global connectivity offered by IoT allows students to be connected to a cloud, where they can have greater access to a pool of shared data and research from large institutions around the world. Most of the "things" in the real world will be stored in a virtual world, allowing them to be accessed at any time. The incorporation of IoT devices in higher education not only supports the teaching-learning process, but also becomes a very important tool for administrative management (Sandoval Carrero *et al.*, 2022), as well as for the creation of smart campus spaces (Gilman *et al.*, 2020). This allows the implementation of a security management system, through sensors, the IoT network allows control and monitoring of student access to the campus, keeping an accurate record of entrances, exits and movements, thus, creating safer campuses. Because the IoT existence allows for the programming of lighting and heating, it leads to cost savings for the institution and reduces energy waste, a fundamental aspect in today's world. Because our planet's resources are limited, and because of the current energy crisis, we must consume energy responsibly.
- Automated feedback and assessment: IoT technology can facilitate automated feedback and assessment. For example, IoT-based real-time assessment systems can provide instant feedback on student performance, identify areas

for improvement and offer personalised recommendations for continuous learning.

6.3 What are the challenges of incorporating Internet of Things in higher education?

The process of adopting IoT technology takes place when there is a degree of harmony between different factors. In other words, the incorporation of the IoT can have numerous benefits, but presents challenges that need to be addressed. With this in mind, this study has been able to identify some of the factors or barriers influencing the adoption of IoT in Higher Education:

- Infrastructure and connectivity: the implementation of IoT technology in education has resulted in a new educational scenario that requires the integration of various technological resources. However, one of the main problems in higher education lies in the lack of sufficient equipment of smart devices in institutions. Therefore, the implementation of this technology represents an economic challenge for university institutions (Veintimilla *et al.*, 2018), which hinders the ability to offer innovative and quality education.
- Privacy and security: IoT applications in education have also raised other scenarios of concern. Having more connected smart devices increases vulnerabilities or cyber attacks in institutions (Georgescu and Popescu, 2015), leading to a rethinking of cybersecurity strategies. Similarly, many of the connected devices will collect student data such as their movements, which is a concern for the educational community to determine the ownership of the data generated, who uses it and how (Grama and Vogel, 2016). Therefore, a clear privacy policy should be established that defines how data collected through IoT devices is collected, stored and used.
- Training and professional development: its adoption is a challenge for university institutions, and it is necessary for institutions and their professionals to commit to the immersion of these resources in the classroom, as well as to promote digital training for teachers to prepare them to tackle complex IoT projects to significantly change the teaching-learning model for a more innovative one in line with the new realities of students.

These challenges must be proactively and carefully addressed to ensure effective and ethical implementation of IoT in higher education. By overcoming these obstacles, educational institutions can harness the potential of IoT to improve teaching, learning and the overall student experience.

7. Conclusions

In the last decade, technology has brought about changes in society at a dizzying pace. This has contributed to the education system's challenge of immersing itself in new smart devices that have burst into institutions, bringing about a change in the way we have understood teaching until now. The adoption of IoT in higher education institutions is happening at a very slow but promising pace. From the results obtained, it can be concluded that the implementation of IoT in higher education is still in its early stages, but it is shaping up to transform education and support the learning process, creating a wealth of opportunities for teachers, students and researchers around the world, thus, increasing the quality of university education. It is, therefore, our hope that university institutions will use this data to continue to transform classrooms by adopting these emerging resources, with the aim of

making the university an innovative learning space adapted to the needs and demands of the 21st century.

8. Limitations and future research

This review is not without limitations. This review sought to analyse quality studies, selecting only "articles" as the document type. This has limited the number of articles selected for the review. It is important to keep in mind that the selection of articles in a systematic review is based on predefined inclusion and exclusion criteria, and may be influenced by the availability of literature and the quality of available studies. The limited number of articles identified may have implications for the representativeness and generalisability of the results. Future researchers may wish to examine other types of papers to compare results and other viewpoints regarding the adoption of IoT in higher education. As a result, of the 11 studies selected, only two provide quantitative data.

Among the future lines of research, it is intended to continue investigating how the so-called emerging technologies, including the IoTs, Blockchain or Big Data, can transform higher education institutions.

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