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Exploring the Educational Transformations: A Systematic Literature Review on the Influence of the Internet of Things in Higher Education

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Abstract

The rapid growth of the Internet of Things innovations stimulates higher educational institutions to invest in and adopt these technologies to support and enhance their learning and teaching strategies. This study aims to investigate the influence of the Internet of Things on teaching and learning in higher education, performing a systematic literature review. Therefore, this research focuses on the following research questions: R-Q1: What are the benefits of the Internet of Things for teaching and learning in higher education? R-Q2: What are the limitations of the Internet of Things for teaching and learning in higher education? The systematic literature review, including the search strategy, the inclusion and exclusion criteria, and the review of the titles, keywords, and abstracts, identified a total of 31 results, mainly journal and conference articles. The findings from the extracted articles in this review were grouped into eleven themes: adoption, personalized learning, learning efficiency, intelligent teaching, collaboration and connectivity, creativity, health and safety monitoring, latency time, security and privacy, quality and ethics, and financing issues. The findings suggest that the Internet of Things can enhance the learning quality, improve the gained knowledge, and reduce costs in higher education. Therefore, adopting a consistent Internet of Things implementation strategy is essential to address identified limitations in higher education.

Keywords: internet of things, systematic literature review, teaching and learning, collaboration and connectivity, higher education

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1. Introduction

According to current predictions, the Internet of Things (IoT) devices will almost triple from 9.7 billion in 2020 to more than 29 billion in 2030 (1). The rapid growth of IoT innovation also stimulates higher educational institutions to invest in and adopt these technologies to support and enhance their learning and teaching strategies (2).

The term Internet of Things (IoT) is coined as "uniquely identifiable objects/things and their virtual representations in an internet-like structure" (3, p. 6125). The primary goal of IoT adoption varies in the field and is to transform every organization's operations (4). Additionally, this aspect motivated educational institutions to develop strategies to help students and their development while utilizing current teaching methodologies (2). Teaching and learning aim to facilitate physical space interaction, information transmission, or education, and thus IoT innovation should support learners in areas such as personalized learning, interaction, mobility, and accessibility (5–10).

Utilizing the benefits of user-friendliness and connectivity of social networks, the IoT aims to incorporate devices into users' daily lives (11). Thus, integrating IoT innovation in education supports a forthcoming enhanced education that is more connected and collaborative. IoT innovation allows educators to track student's learning progress in real time and improve students' access to learning resources and communication channels (12–14). Incorporating IoT in education enables the use of cutting-edge technologies, the personalization of the teaching and

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learning processes, the enhancement of educational interest, and education focused on creativity. In other words, intelligent, personalized, and adaptive higher education (15).

Given that IoT is an emerging area of interest in education, it includes both formal or traditional learning and informal learning, such as social media, MOOCs, game-based learning, etc. (16). Another benefit of integrating IoT in education is lower education costs and provision for high-quality educational materials compared to current methods and implementing open, affordable, and well-guided global training settings, which is education's most significant challenge today (17). Consequently, an essential tool, such as IoT, is required for institutions to survive in the modern era to provide technology-savvy students with superior instructional methods.

The literature shows that educational institutions have not fully embraced IoT technology and face many challenges, such as privacy, ethical issues, and security (18,19). Therefore, a deeper understanding of IoT technology is required to enable education for its adoption. In addition, IoT use in education is advantageous, but it presents some new difficulties for its execution. While there are studies on the use of IoT in education, more research is needed, especially in higher education. This study aims to investigate the influence of IoT on teaching and learning in higher education, performing a systematic literature review. Therefore, this research focuses on the following research questions:

R-Q1: What are the benefits of the Internet of Things (IoT) for teaching and learning in higher education?
R-Q2: What are the limitations of the Internet of Things (IoT) for teaching and learning in higher education?

The study's conceptual framework is illustrated in Figure 1 and presents the influence of IoT on the student's learning experiences, teaching process, privacy, security, and ethical issues.

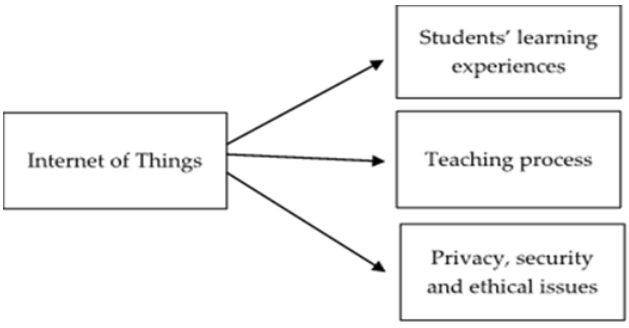

Figure 1. Conceptual framework

This study is organized as follows. The first section presents the purpose of the research, the problem statement and defines the research questions. The second section presents the methodology of the study. The third section discusses the results of the research. Section four includes the conclusion and recommendations of the study.

2. Methods

According to Dresch et al., "Systematic literature reviews are secondary studies used to map, find, critically evaluate, consolidate and aggregate the results of relevant primary studies on an issue or specific research topic, as well as to identify gaps to be filled, resulting in a coherent report or synthesis" (20, p. 129). Performing a systematic literature review entails distinct activities that can be clustered into three main phases, specifically: the planning, the conducting, and the reporting of the review (21). This study aims to investigate the influence of IoT on teaching and learning in higher education, performing a systematic literature review.

2.1. Planning the review

The first phase of performing the systematic literature review is planning the review process by refining the research objectives into a set of research questions, more specifically:

R-Q1: What are the benefits of the Internet of Things (IoT) for teaching and learning in higher education?
R-Q2: What are the limitations of the Internet of Things (IoT) for teaching and learning in higher education?

When conducting a secondary study, such as a systematic literature review, it is essential to produce a protocol for the planning phase that must be followed thoroughly (21). Any conditions, such as the quality and the inclusion/exclusion criteria, are entailed in the protocol. The objective of having a protocol is to reduce the bias in the study by describing how the systematic review will be conducted in advance (21).

2.1.1. Search strategy

The search strategy was initially performed using the digital library of the London Metropolitan University (https://emu.londonmet.ac.uk/). However, the identified studies in line with the research objective were limited. It was imperative to consider searching using alternative databases to obtain a comprehensive view when answering the questions. The electronic databases used in this study are the digital library of the London Metropolitan University, IEEE Xplore, Google Scholar, and ResearchGate. The identified research items are mainly journal articles and conference articles. The following keywords were used as part of the search strategy: "Internet of Things AND higher education," "Internet of Things AND teaching," "Internet of Things AND learning," and "Internet of Things AND teaching AND learning in higher education."

2.1.2. Inclusion and exclusion criteria

The following inclusion and exclusion criteria were used to determine whether an article should be included in the systematic literature review, as illustrated in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published articles from 2017 to 2023	Articles that do not investigate IoT technology
Peer-reviewed publications	Articles that do not focus on higher education
Written in English	Articles with no access to the full text
Relevant to the research questions	Articles that are not peer-reviewed
Empirical research and an experience article	Magazines, reports, trade publications, and news

2.2. Conducting the review

This section describes the process of conducting the systematic literature review.

2.2.1. Study search and selection

Following the search strategy, the selected electronic databases were searched. Initially, the search yielded 1057 results. The available "full text" reduced the results to 992, the publication date range 2017-2023 was applied, and the results were reduced to 803; after removing the results that were magazines, reports, trade publications, and news, 606 results remained. Then, the overall results that were not peer-reviewed were excluded, with 423 results remaining. Then, reviewing the titles, keywords, and abstracts, excluding those not focused on the research field, a total of 31 results, mainly from journal and conference articles, were selected to be considered in this systematic literature review.

2.2.2. Data extraction and synthesis

In this study, the required details were extricated via a Microsoft Excel spreadsheet, and the extracted details are shown in Table 2.

Table 2. Extracted data and details

Extracted data	Details
Article ID	Unique paper recognition
Article title	Name of the article during the search
Publishing date	The publication year
Type of Study	Journal article, conference paper
Research methods	Qualitative, quantitative, or mixed-method

3. Results

Out of the identified 31 studies, 7 are conference papers, and 24 are journal articles. From the overall 31 studies, about 52% employed the quantitative method, about 32% employed the qualitative method, and about 16% employed mix method. Regarding the years of publication, more articles were published between 2020 and 2021 (13 articles), two articles in 2022, and five articles in 2023. The complete list of articles is represented in Table 3.

Table 3. Profile of articles

I.D	Article title	Date	Type of Study	Research methods
1	A Survey on IoT in Education (22)	2018	Article	Quantitative
2	Internet of Things in Higher Education: A Study on Future Learning (12)	2017	Article	Quantitative
3	Investigating the Impact of the Internet of Things in Higher Education Environment (19)	2021	Article	Quantitative
4	How Internet-of-Things (IoT) Making the University Campuses Smart? Q.A. higher education (QAHE) perspective (10)	2018	Conference article	Qualitative
5	Role of Internet of Things (IOT) in Higher Education (23)	2018	Conference article	Qualitative
6	Automation of Class Attendance and Enhancement of Student Academic Performance Using IoT in Higher Education (24)	2018	Article	Quantitative
7	IoT and Big Data Technologies: Opportunities and Challenges for Higher Learning (18)	2020	Article	Qualitative
8	The Higher Education Students' Perception on IoT Acceptance as an Educational Facilitating Medium: Perception from Omani Context (25)	2023	Article	Quantitative
9	Predictable Influence of IoT (Internet of Things) in the Higher Education (26)	2017	Article	Quantitative
10	Usage of Internet of Things (IOT) Technology in the Higher Education Sector (27)	2021	Article	Qualitative
11	Towards Next Generation Teaching, Learning, and Context-Aware Applications for Higher Education: A Review on Blockchain, IoT, Fog and Edge Computing Enabled Smart Campuses and Universities (6)	2019	Article	Qualitative
12	The IoT Technologies Acceptance in Education by the Students from the Economic Studies in Romania (28)	2021	Article	Quantitative
13	A Smart Education Model for Future Learning and Teaching Using IoT (8)	2020	Conference article	Qualitative
14	Smart Educational Learning Strategy with the Internet of Things in Higher Education System (14)	2021	Article	Quantitative
15	Exploring the Potential of IoT-Based Learning Environments in Education (29)	2023	Article	Mix
16	IoLT: An IoT based Collaborative Blended Learning Platform in Higher Education (30)	2018	Conference article	Qualitative
17	Effective Learning in Higher Education in Malaysia by Implementing Internet of Things related Tools in Teaching and Introducing IoT courses in Curriculum (31)	2019	Conference article	Quantitative
18	Readiness to Adopt the Internet of Things at the University of KwaZulu-Natal (32)	2018	Conference article	Quantitative
19	Towards a framework for Internet of Things and Its Impact on Performance Management in a Higher Education Institution (33)	2021	Conference article	Qualitative
20	Exploring the Romanian Students' Intention to Use the Internet of Things for Sustainable Education (34)	2021	Article	Quantitative
21	Design and Satisfaction Analysis of Embedded IoT Course (35)	2019	Article	Quantitative
22	The Importance of Using the Internet of Things in Education (36)	2023	Article	Quantitative
23	IoT-Based Model for Intelligent Innovation Practice System in Higher Education Institutions (37)	2021	Article	Mix
24	IoT in Distance Learning during the COVID-19 Pandemic (38)	2020	Article	Qualitative
25	An Integral Pedagogical Strategy for Teaching and Learning IoT Cybersecurity (39)	2020	Article	Mix
26	The Smart Classroom: A New Frontier in the Age of the Smart University (9)	2020	Article	Qualitative
27	Challenges and Opportunities in the Internet of Intelligence of Things in Higher Education—Towards Bridging Theory and Practice (40)	2023	Article	Mix
28	Real-Time Monitoring of Physical Education Classroom in Colleges and Universities Based on Open IoT and Cloud Computing (41)	2021	Article	Quantitative
29	Application of 5G Internet of Things Technology in the Design of Physical Education Platform (42)	2022	Article	Quantitative
30	Research on Intelligent Campus and Visual Teaching System Based on Internet of Things (43)	2022	Article	Quantitative
31	IoT Adoption Model for E-Learning in Higher Education Institutes: A Case Study in Saudi Arabia (44)	2023	Article	Mix

4. Discussion

The last phase of performing the systematic literature review is reporting the review. This research aims to identify the benefits and limitations of IoT for teaching and learning in higher education based on the selected studies.

4.1 Benefits of the Internet of Things (IoT) for teaching and learning in higher education

Addressing the first research question, "R-Q1: What are the benefits of the Internet of Things (IoT) for teaching and learning in higher education?" from the systematic literature review, the following themes were identified:

Adoption: Teachers and students can engage with instructional materials thanks to the adoption of the IoT in educational settings (19). Those trained to use IoT technologies tend to think that these applications are practical, straightforward, and easy to use, increasing their intention to use them (25). They also believe that the likelihood that someone will use these technologies increases significantly if there are favorable conditions for doing so (28). Research shows that appropriate supervision and training, favorable conditions, and simplicity of use are all highly related to the intention to adopt IoT technologies (22,28,34,44). Education policies are essential for supporting technology adoption in classrooms and its effective integration into educational programs (19). Nonetheless, university students lack sufficient knowledge and comprehension regarding the benefits of IoT devices and services for their academic performance. Stated differently, research suggests that university students lack sufficient knowledge about how IoT services might enhance their learning opportunities (25).

Moreover, staff in administrative positions still oppose the IoT's use, making it difficult for IoT's adoption in education. An IT department is typically present at academic institutions to handle hardware and software infrastructures. Since the department is not involved in the field of education, it cannot provide teachers and students with support regarding the use of technology in the classroom (40). This remains true despite the fact that many academic institutions have established instructional technology sections to bridge this gap. Unfortunately, instructional technology specialists lack in-depth expertise in IT, particularly IoT. This problem can only be solved by providing continual IoT professional development training at the cutting edge of teaching and learning, specifically for professors and teaching assistants (40). Nonetheless, ultimately, for learning to advance, educators must be able to choose the appropriate technology and effectively adopt it in the classroom (19).

Personalized learning: Every learner learns differently and at a different pace. As a result, educators cannot frequently monitor and address these variations in students' learning preferences and rates of accomplishment. The IoT can facilitate this, sourcing real data during learning through wireless technology-based formative assessments and assisting teachers in modifying and personalizing instruction for each student (36). This suggests that IoT-based learning can result in a more interesting and pleasurable learning environment for students, which is likely to contribute to improved learner-centered learning outcomes (29).

The IoT utilizes interactive systems to improve students' and teachers' cognitive abilities (14,37,41,43). Students can access limitless material to perform research, homework, or other assignments with personalized learning by interacting with many ordinary devices that are connected to the web (6,12,14,19,23). Through multiple multimedia sensors sending information to a central server, IoT innovation links the classroom to real-life environmental circumstances, such as the number of students present, the temperature of the space, and student activity, among others (8). Students can develop their capacity for critical thought and problem-solving through interactive learning (9,10,43). The collection of personalized feedback advances personalized learning by assisting educators in meeting and addressing learners' needs (31,35,39,42).

Learning efficiency: The goal of the education sector is to improve the learner experience, increase efficiency, and provide essential, effective teaching and learning environments based on the needs of the learners (12,18,24). A variety of different IoT applications assist academic staff, enabling teaching and learning initiatives to enhance the student experience where every student can post and receive information on the platforms (9,27,31). The student's commitment to intelligent learning raises curiosity levels and facilitates efficient learning through entertaining activities (14,44).

Intelligent teaching: The advancement of intelligent education has been promoted through the use of IoT (23,30,37). IoT enables the teaching staff to deliver new teaching and evaluation models, gather student feedback quickly, and calibrate pedagogical techniques in order to improve the effectiveness of the teaching activity (6,8,12,19,27,30). Using IoT, the lectures are interactive, recorded, and made available to students at any time, in contrast to traditional education, which is time-bound (36). Teachers can monitor students' progress and boost their overall performance to help them complete a course using facial recognition for student identification, facial expression recognition for understanding students' emotional states, and grouping attendees based on their behavioral parameters (38). Additionally, IoT enables educators to leverage specialized learning services (such as online programming competitions), advanced online learning environments, and cutting-edge teaching strategies like the Flipped Classroom or amplification (6).

Although there are challenges in creating and implementing successful IoT-based lessons, teachers are generally in favor of IoT-based learning and see its potential to be successfully integrated into their teaching practices (29). Even though educators comprehend the concepts of IoT but not its specifics this is insufficient for

the implementation of IoT in education because teachers cannot fully explore and utilize the full range of IoT capabilities unless they have a thorough understanding of the details (40).

Collaboration and connectivity: IoT offers a large open interactive platform that improves collaboration in higher education institutions at various levels (22,32,33). The essential factor for collaboration is efficient communication. Smart campus/university technologies can promote collaboration and cooperation among users (students and teachers) and provide better access to all resources, such as communication and learning materials, also enabling teachers to monitor students' development in synchronous mode (6,26,29,36). With the ability to connect people and things regardless of time or place utilizing any network or service, the IoT in higher education has a positive impact on intra- and extra-university connectivity (19,22,33).

Creativity: IoT is changing how teaching and learning are done and are recognized as great creative tools (24,38). Educational applications that make use of the IoT are powerful creative tools that are revolutionizing traditional methods of teaching and learning (36). Moreover, enables the creation of 3D graphics textbooks with videos and note-taking functionality for teachers and students (24,37). The diversity of the IoT fosters creativity with intelligence actions and can change the existing field into a new one (26,32).

Health and safety monitoring: Access to health care services and a safe environment are crucial in any educational institution since students' health and safety significantly influence their overall academic performance (27). The use of IoT includes keeping track of students' health and safety (6,10,33). Moreover, higher education institutions can benefit significantly from the use of IoT to improve security, where students can be tracked around the clock, and their presence can be reported at any time with the aid of technologies like 3D location (10,24). IoT includes low-cost security camera technology, student-accompanied crewless aerial vehicles, smoke and vape detectors, and other innovations that increase students' confidence in the stability of their learning environment and possibly promote positive behaviors (33).

4.2 Limitations of the Internet of Things (IoT) for teaching and learning in higher education

To address the second research question, "R-Q2: What are the limitations of the Internet of Things (IoT) for teaching and learning in higher education? From the systematic literature review, the following themes were identified:

Latency time: The expansion of learning technologies and the rise in audio and video instructions increases the demand for content; thus, it is necessary to reduce latency time in the institutions' enterprise architecture (6,27,33). A set of standards should be established for data format and make sharing and managing sensory data simple since cloud computing technology is complex to govern completely and effectively (10). To handle this data during online courses, IoT must give a more flexible and strict service level (27,33).

Security and privacy: Different security and privacy issues have to be overcome for IoT technology to be successfully implemented in the higher education sector (10,12,18). The deployment of IoT technology in higher education may lead to new and unusual privacy and security concerns; thus, the primary goal should be to address issues and concerns to ensure the security of IoT devices and services (33,40,44). There are many IoT devices and sensors, which raises the risk of malicious software efforts and necessitates additional layers of security (19). Additionally, security challenges appear because security measures, including firewalls, robust password strategies, encoding, and antivirus software, do not adequately protect high-tech advances. The learner's privacy is a challenge that the IoT has not addressed either (18).

Quality and ethics: The digital classroom emphasizes the many ethical standards, academic integrity, plagiarism, and data fraud among students in scientific societies. To better research and address these ethical challenges in higher education institutions, IoT-based educational applications, various tools, and technologies for teachers and scientific communities should be developed (12,18,27,33). The identification of methods for the preservation of private data, as well as challenges of individual consent, data ownership, and openness, provide ethical concerns (18).

Financing: Since content and application stacks are growing, the overall cost of I.T. systems is rising yearly (29). Most organizations lack a plan for splitting the expense of the whole IoT infrastructure. Budgetary restrictions apply to them as well. As a result, new financial, I.T. infrastructure, and service models must be introduced in the higher education industry (12,19,27,33).

5. Conclusion, recommendations, limitations, and future work

5.1. Conclusion

IoT in higher education is a new conceptual paradigm still in its early stages, and this innovation is expected to change the educational landscape in the following years significantly. The current study presents the benefits and limitations of IoT in higher education for teaching and learning. The performed systematic literature review can serve as a foundation for developing a thorough understanding of how IoT devices and applications have impacted higher education. In addition, the systematic literature review exhibits that the interest in using IoT has effectively spread in the higher education domain and has been followed by increased research publications. IoT's potential benefits and limitations in higher education for

teaching and learning are presented, demonstrating the existing literature gap. IoT innovation offers many benefits for higher education, but innovations that fully address pedagogical teaching and learning settings are not yet entirely placed. As mentioned in the introduction, IoT provides various benefits for educational environments, including the ability to track learner actions. As a result, IoT can enable educational institutions to solve student challenges through study activities immediately. The findings from the extracted articles in this study were grouped into eleven themes: adoption, personalized learning, learning efficiency, intelligent teaching, collaboration and connectivity, creativity, health and safety monitoring, latency time, security and privacy, quality, and ethical and financing issues. Overall, the systematic literature review shows that the integration of IoT in higher education for teaching and learning offers certain benefits, and there is a need for further research to enhance the field.

5.2. Recommendations

It is imperative that stakeholders consider emerging IoT innovations and actively use them in higher education in the adoption process to expand teaching and learning. Therefore, adopting a solid IoT implementation strategy is essential. Furthermore, IoT in higher education needs to address some crucial limitations like latency time, security and privacy, quality and ethical, and financing issues, as identified from the literature (10,12,18,19,27,33). Addressing these challenges, IoT will provide the best possible experience for students, teachers, and other stakeholders. However, no models or frameworks offer explicit rules for IoT integration in higher education for teaching and learning. The IoT deployment in higher educational institutions faces various challenges, including good planning, practical instruction, and decision-making. Integrating IoT in higher education faces several challenges in terms of organizational settings; thus, it is crucial to consider the stakeholders' viewpoint and ability to adapt. It is hoped that the results of this analysis will help all the stakeholders, especially university policymakers, make better choices about integrating and using IoT for teaching and learning. The findings suggest that IoT can enhance the learning quality, improve the gained knowledge, and reduce costs in higher education.

5.3. Limitations and future work

The primary limitations when performing a systematic literature review are biases related to selection and publication, data extraction inaccuracy, and data misclassification. Selection bias describes how criteria used to choose articles might skew statistical analyses (45). The research questions were thoroughly followed to define keywords for the database search using the established inclusion/exclusion criteria to mitigate this bias (46). Publication bias occurs because researchers are more inclined to focus and publish only the positive results of their research, and they are less likely to publish the negative results because it is more challenging to publish unfavorable results in peer-reviewed publications (45). To mitigate these biases in the systematic literature review, a search was conducted across the four most widely used databases that yielded more results to review, suggesting an increase in articles reporting negative results. Data extraction inaccuracy and misclassification allude to the possibility for reviewers to extract and interpret material differently (45). To address these biases, at least two authors should carefully read the whole text of each retrieved study (45). Therefore, this strategy was adopted in the paper, where all the extracted material was thoroughly considered to compensate for this limitation and possibly mitigate the biases (45).

This study is anticipated to motivate researchers to utilize the findings to support their studies and spur further investigation in the field. They are encouraged to use this research as a foundation for future reviews investigating the innovation ecosystem related to integrating the Internet of Things in higher education and how it may change.

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