Investigating Internet of Things Impact on e-Learning System: An Overview

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***Abstract*—e-Learning systems have reached their peak with the revolution of smart technologies. In the past few years, the Internet of Things (IoT) has become one of the most advanced and popular technologies, affecting many different areas. Using IoT in an e-learning system is a fantastic technology that improves the e-learning system and makes it more inventive and cutting-edge. The key challenge addressed in this study is the acceptance of IoT usage in e-learning systems as well as how to improve it so that it can be utilized properly. This research concentrates on how IoT can benefit e-learning systems and how it might benefit users of e-learning systems. A comprehensive literature review was conducted to get acquainted with the important research related to IoT technology and e-learning systems through online research databases and reliable scientific journals. The first research finding is that e-learning systems need such modern techniques as IoT to enable interconnection, increase reliability, and enhance the enjoyment of the educational process. The second result is that research related to the development of new technologies like the IoT has a significant impact on enhancing the performance of new systems and bringing about positive change. This study highlights the value of IoT, particularly in e-learning systems. It aids in the development of new strategies that will improve the efficacy of e-learning systems and stimulate researchers to develop advanced technology.**

Keywords*—e-Learning system; Internet of Things (IoT); software system; education, learning process

I. Introduction

IoT can deliver unique services in a variety of domains. The IoT connects many devices and things to form a physical network that includes sensing, communication operations, and processing without the need for human involvement. IoT devices have increased dramatically during the previous decade, and by 2025 they may reach 50 billion devices [1]. The IoT is already attracting a slew of academic and business interests. Smarter and smaller devices are introduced in a variety of IoT domains every day, including monitoring management, smart houses, smart vehicles, smart farming, smart tourism, e-health, and e-learning, to mention a few [2-9].

e-Learning refers to using electronics and the Internet in addition to software applications in the learning process and thus making it more effective and dynamic [10-12]. Some of the drawbacks of traditional e-learning systems include limitations in expanding and distributing computing power, as well as exchanging information among system users [13], which has encouraged the development of new technologies to overcome these obstacles and motivate the learning process [14]. e-Learning is a key part of making education better, and it is the main way for teachers to improve their skills and abilities by adapting to new scientific methods [15]. The use of techniques in e-learning like virtual classrooms improves the knowledge of learners and transforms the educational process into a universal one [16]. The evolution of technologies and communication enhanced the e-learning environment and gave it the nature of expansion through the combination of physical and virtual objects. IoT as one of these technologies has a strong influence and benefits on different fields [17], education is considered one of these fields which plays a key role in its development and quality [18]. e-Learning as part of the education system was also greatly impacted by this modern technology [19]. Students build their knowledge by enabling them to explore the reality around them [20]. IoT converts traditional e-learning into intelligent and interactive e-learning by integrating smart objects. Using smart objects provides learners with good communication and interaction with instructors and other parties from anywhere [21]. IoT motivates students and teachers. It creates an appropriate and comfortable learning environment in addition to increasing performance [22].

For many years, IoT has been used in conjunction with e-Learning. However, under certain circumstances, such as the COVID-19 epidemic, all learning processes have had to totally migrate to e-learning platforms [23, 24]. As a result, the significance of such integration has grown [25]. Still, many educational institutions have had a hard time making the switch to e-learning [26]. This is due to several factors, such as a lack of knowledge, student acceptance, a lack of infrastructure, and a lack of clear guidelines for integrating IoT with e-learning. Also, technical problems with accessibility, design flexibility, interactivity, the system, and the quality of the Internet will affect the stability and continuity of e-learning [12, 27]. There is a continuous change in the methods of the learning process. Therefore, it is necessary to propose and develop new supportive methodologies in order to fulfill the requirements of learners all over the world [28] and achieve satisfactory e-learning outcomes [29]. Accordingly, this article will concentrate on

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the issue of a lack of guidelines to provide a conceptual and clear understanding of the IoT and e-learning processes.

This paper makes a big difference by giving an in-depth look at how the Internet of Things (IoT) is being used to make e-learning better now. This survey includes highlights of the responsibilities of IoT entities when integrated with the e-learning process. This study examines recent research efforts aimed at addressing the deployment of IoT in the e-learning process as well as open research opportunities for future research. This study makes the following contributions: In addition to discussing IoT concepts and e-learning process concepts, it also includes an analysis of the operational deployment of the IoT in the e-learning process as well as IoT e-learning architecture and entities.

The rest of the paper is organized as follows: Section II discusses the research background of IoT technology and e-learning systems. Section III discusses the related work in this field. Section IV explores the methodology applied in this research. Section V discovers the research and analyzes the findings. Section VI, VII and VIII discuss about the tools, architecture and entity model of IoT e-learning. The challenges and future directions of IoT and e-learning integration are discussed in Section IX. Finally, the paper is concluded in Section X.

II. BACKGROUND

A. Internet of Things Overview

The main idea behind IoT is to collect data from their surroundings before analyzing it in order to execute automated operations to assist users. The IoT is gradually gaining ground worldwide. Modern technology has grown in the past few years, in part because sensors and smart devices have become more common [30, 31]. The three stages of IoT activities, including data collection, transmission, and processing, are described below [25, 32-34]. In e-learning, data collection, transmission, and processing are very important parts of how online educational content is delivered and how well it works. This is done by gathering and analyzing data from different sources. It is possible to gain valuable insights into student performance and engagement, which can be used to tailor the e-learning experience [35]. These stages can be summarized as follows:

- Data collection: The first phase is data collection, which includes detecting and obtaining data through various communication methods. To identify and gather data, several technologies such as Bluetooth, Near Field Communication (NFC), Global Positioning System (GPS), and Radio Frequency Identification (RFID). When integrating IoT with e-learning, this phase entails receiving information from a variety of sources, including student interactions with the e-learning system, course content, and assessments. A range of techniques, including online applications, polls, monitoring tools, and application logs, can be used to gather data [35].
- Data transmission: Transmitting the data is the second phase where the gathered data is transmitted to the servers or host system for processing via a specific medium (e.g., wireless or wired) and protocol (e.g., IEEE 802.3/802.11 standard). Because falsification tendencies are low, wired transmission channels may send more precise and dependable data. However, wired networks may not be useful for long-distance communication. It is also rather pricey when compared to wireless options. Understanding the optimum transmission route and the geography of the surroundings is critical. When integrating IoT with e-learning the data has been collected about students, it needs to be transmitted to the e-learning systems for storage and analysis using secure networks or cloud-based storage systems [36]. Furthermore, data management systems may be used in combination with data transmission to structure and store the data to be used later [36].
- Data processing: This is the final phase, during which the data sent should be properly reviewed and processed in order to make a decision. Data will go through many preparations, cleaning, classifying, and filtering procedures during this phase. Cloud computing allows services to be administered remotely and provides processing resources and virtual storage. In this stage when e-learning is integrated with IoT, the gathered data is analyzed and processed to get the knowledge that can be applied to enhance the e-learning process. This requires using algorithms and analytics tools to reach conclusions and trends from the data [35] The processed data can be utilized to create reports on student engagement and performance as well as to identify e-learning platform development opportunities [36].

The IoT is a technical improvement in transporting and exchanging data between connected objects using an Internet service [11, 37, 38]. It has the property of quick evolution [39] and the scope has expanded further to connect people to things [13]. IoT gives good control over objects and transforms them into smart objects [14]. Therefore, it is seen as an essential element in the growth of smart environments [40]. The communication and association between physical and virtual objects provide the IoT with the characteristic of being ubiquitous [10]. IoT has devices that let it sense and collect data from other devices, which it then shares for the good of everyone. The association of RFID tags, sensors, and actuators with each other has made this technology a modern and unique model [21]. IoT technologies are different from other technologies because they are everywhere and encourage people to come up with their own independent and smart solutions [41]. It has become a hot and interesting topic among investors in various fields [15]. IoT is distinguished by non-human intervention, use anywhere, no time limit, reducing cost and time, and a perfect connection because it requires high-speed Internet [42, 43]. Fig. 1 explains the most common features of IoT technology, including sensing, connectivity, intelligence, safety, energy, and expression.

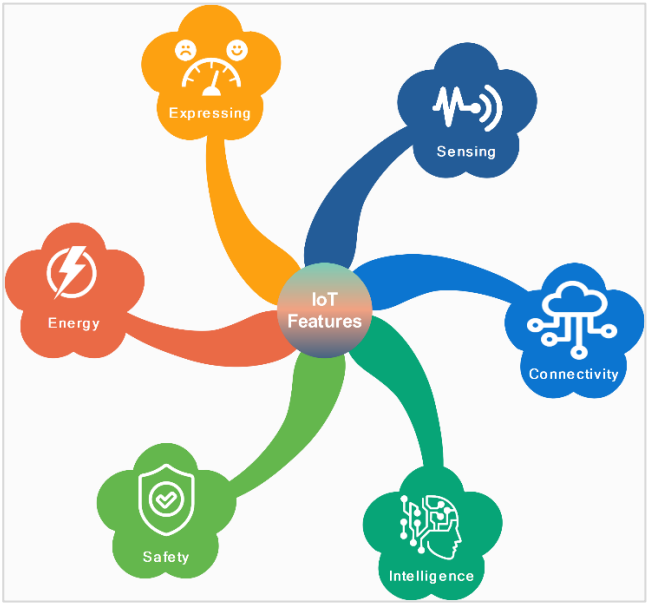

Fig. 1. Internet of Things features.

- Sensing: Many IoT devices are equipped with sensing capabilities that can be used to gather data from the surrounding environment and adapt their behavior based on the gathered data [36]. In order to gather data for a specific circumstance, IoT should be able to read analog signals from various sources such as light, RFID, GPS, and gyroscope. Light and pressure, for example, might be utilized in automobile applications. To produce the optimum use case, a good sensing approach should be used. The gathered data can be used by IoT in adapting their actions based on the context in which they are used systems [36]
- Connectivity: To ensure effective communication between networked IoT system components like computer processors, sensors, and data centers, connectivity is a crucial element to be considered. To achieve this smooth communication, several protocols and standards must be used. IoT systems may communicate and exchange data with one another and with other systems since they are connected through a network. Bluetooth, Wi-Fi, and cellular networks are just a few examples of wireless technologies that are frequently used to facilitate this connectivity [35].
- Intelligence: Data is utilized to create significant business observations and make crucial business choices in practically each IoT use scenario in recent times. On top of this vast data, building computational models to gain significant insights that can enable IoT systems to function independently or with minimal human intervention [35]. The sensor readings are refined and transformed into a format that may be used to train computer models. An appropriate data structure should be considered, depending on business requirements to support decision-making [36].
- Safety: Security is one of the most important aspects of the IoT system [35]. Sensitive data is delivered from terminals to the analysis layers via connection components throughout the whole cycle of an IoT system. To protect data from abuse and exploitation against cyber-attacks, IoT systems must adhere to adequate security procedures such as using secure communication protocols, encryption, and firewalls as well as the implementation of privacy policies and technologies to protect the personal data of users [36, 44, 45]. Every element of an IoT system that is compromised might ultimately cause the entire process to collapse.
- Energy: The entire IoT system requires a lot of energy, from end components to the communication and analysis layer. It is essential to consider design techniques while creating an IoT system so that energy usage is kept to a minimum (IEEE 802.15.4, 2003). For instance, IoT devices can consume less energy by adopting low-power communication protocols and effective power management techniques [11].
- Expressing: To improve the user experience, IoT incorporates multiple cross-domain models. It also guarantees that the structural and operating expenditures are properly balanced. IoT devices must be built in a way that allows them to be readily scalable up or down on request to allow for the integration of a large number of devices and sensors [36]. Providers must address future demands for handling such a large quantity of data when creating IoT processes to satisfy additional business demands to enable the creation of large-scale IoT deployments, such as smart cities or agriculture.
- Interoperability: Regardless of their manufacturer or operating system, IoT systems can work seamlessly with other systems and devices [36]. As a result, a variety of devices and systems can be integrated into IoT systems.
- Distributed Real-time architecture: IoT systems often have a distributed architecture, with devices and sensors located at the edge of the network, rather than centrally located [35]. This decentralized architecture allows for the Real-time collection and processing of data from many devices and sensors.

B. e-Learning Overview

e-Learning technology is a critical component of delivering education through an electronic medium, specifically the internet [46]. Numerous products are available on the market that implement e-learning technologies, which makes it critical for practitioners to be aware of the details of those technologies [47]. The knowledge along with the skills to use e-learning technologies will improve the chances of providing an effective and efficient learning experience for both students and teachers [48]. Because physical connection is banned, e-learning platforms can be used as a substitute for traditional learning and teaching methods. The social dimension is one of the main difficulties for students when

using the e-learning system, which can be reduced by adapting social IoT that can add interest to the virtual educational environment [17]. In order to stop this worldwide epidemic, the world needs more young people who grew up with technology and can quickly adapt to the online world without much trouble. Teleconferencing tools like Skype, Zoom, and WebEx sessions, as well as other similar technologies, can be used by students in online classrooms. Simulcasts, workshops, academic board meetings, and conferences may all be held electronically without having to meet in person. Using this kind of technology to keep people at a social distance is one way to stop the spread of viruses, like the COVID-19 virus, among academics [49]. Online assessment can be done using e-learning platforms, which guarantee the participants' health in such a pandemic. With these kinds of technologies, evaluating students can be done safely because there is less need for physical contact [50]. In the workplace, an internet platform can be used to do things like surveys, staff evaluations, and interviews. This helps keep employees safe.

e-Learning technologies can be categorized into two levels, infrastructure and software. The infrastructure category is further categorized into on-premise and on-cloud [51]. On-premise technology is the infrastructure that uses the local hardware of the educational institution, while on-cloud computing uses cloud computing resources over the Internet [52]. For instance, e-learning infrastructure includes the underlying hardware such as servers, end-user devices such as mobiles and desktops, networking devices, input devices, output devices, and storage devices [53]. Those can be on-premise, which means that the hardware used in e-learning is located on the campus of the educational institution [54]. On-premise infrastructure needs help and skills all the time, but it also gives you more freedom [55]. Using cloud computing also has numerous advantages as it reduces cost and increases flexibility and real-time scalability, but at the same time, it may introduce some issues regarding dependency, security, and confidentiality [56-60].

Likewise, the software category is classified into synchronous and asynchronous technologies. Synchronous technologies support real-time communication, whereas asynchronous technologies support communication at different times and locations but do not support real-time communication [17]. In terms of software, e-learning uses both synchronous and asynchronous tools. Synchronous tools are trying to mimic traditional classrooms and, to some extent, improve the experience of learning by augmenting technological tools that may improve the education process [17]. Synchronous technologies include video and audio conferencing, live chat, whiteboarding, and application sharing [61]. While asynchronous can be combined and formed in learning management systems that support learning resources management, forums, messaging, assessments, and announcements [62].

III. Related Work

Previous literature on improving IoT and e-learning may be divided into numerous areas, such as content management and sharing, creating solutions, e-learning content distribution, tracking the e-learning process, e-learning tool interoperability, and standards interoperability [63]. The value of the IoT was demonstrated by [64] by developing and enhancing education, as well as the scope of their significance in higher education institutions via smart coursework utilizing the latest methods in the classroom setting, smart labs to run tests more efficiently and enable tests, including the use of gadgets to enhance student communication with their classmates and teachers, and also scientific content. Mohammed and Isa [25] emphasized the significance of IoT in enhancing human-machine connection, which contributes to people's social isolation. The use of IoT to prevent the spread of infections (such as COVID-19) may face unique challenges, especially in developing countries with limited telecommunications infrastructure. In the same way, IT expertise is required when dealing with IoT apps or devices. Individuals prefer to interact personally with another person rather than with a machine. Others may believe that revealing medical details to the machine will compromise their privacy. Such factors represent considerable obstacles to the use of IoT applications to control the virus's spread [25].

Dodero, et al. [65] look at what needs to be done to make the e-learning future a reality. Issues related to IoT and e-learning integration, including CPU and storage limitations, throughput, and bandwidth constraints, should be addressed for successful integration. Accordingly, the trade-off between data-collection efficiency and interoperability may be considered to enhance this integration [65]. In their work, Chituc [66] looked at standards interoperability and pointed out the problems with interoperability that need to be fixed for the IoT and e-learning visions of the future to come true. Perales, et al. [67] demonstrated an online system utilized by the International University of La Rioja. The online service is a remote online lab that delivers experiential learning using engineering experimental tools. The teacher might move from one online workspace to another to help students with their lab instructions. Even though this method is used to offer online labs, it doesn't consider how and why the students interact with each other. In the work of [68], the authors recommended using a context-aware system to capture a vast amount of data about the learner's surroundings. The system automatically adjusts to the customer's wishes based on these facts. Context-awareness incorporation into an e-learning system would be an effective strategy for improving learning.

Zaguia, et al. [24] showed learners a new way to use synchronous e-learning for intelligent e-learning. The paradigm is a new way of thinking about distance learning in which the teacher has more control over the students. Tools for artificial intelligence, IoT, and virtual reality are put together to make a more powerful system that helps the teacher keep an eye on the students during lessons and tests. Most of the changes we will make to our systems in the future will involve adding more computer-aided services to help teachers see and respond to how students are acting. In the work of [69, 70], the authors proposed that artificial intelligence approaches such as data mining and fuzzy logic be used to smarten up e-learning tactics and augment students' learning. Most of these systems are limited by the time to finish the assessment exam, the learner's evaluation criteria, history, and so on [24]. Similarly, Leahy, et al. [71]

investigated the role of emergent technology, such as smart materials, artificial intelligence, and augmented reality, in the future of e-learning. In Zhang and Zhou [72], the importance of locality, interaction, intelligence, openness, and cloud computing were analyzed from the standpoint of e-learning's future vision.

The use of smartphones in e-learning was emphasized by [73]. These gadgets must be integrated into distance learning systems. These gadgets became more widely available and easier to operate as time went on. The authors suggest a platform that has an intelligent agent on a student's smartphone. The necessary information about the students' obsessions, participation in the course, and other factors is collected and sent to the artificial intelligence system for evaluation. The artificial intelligence algorithms look at student data, comments, and ratings of course materials to figure out what course content is suitable. The authors suggested analyzing student behavior with smartphones to make sure that the course content was customized correctly. Tobarra, et al. [74] put the app of the virtual laboratory to the test to see how well it worked. The learners' acceptance was evaluated using the Unified Theory of Acceptance and Use of Technology (UTAUT) model, as well as time allocation, learner's behavior in relation to evaluation items, and material sources. The main result of this research is that the suggested lab has a high level of student acceptability, as measured by several factors (ease of use, perceived usefulness, attitude, intention to use, social influence, and estimated effort).

IV. Research Methodology

This study aims to find out the use and importance of integrating IoT with e-learning systems. The strategies and rules presented by [75-79] were adopted in the review process of this paper. Fig. 2 explains the review activities. The study begins with a review of the literature and a survey of the research object's e-learning implementation, followed by a summary of the significant results from the associated literature. Following that, identified a research need from which derived review questions and objectives. Finally, the paper's importance and scope were determined. There were a lot of publications that were looked at, but this review only includes the most important and recent (since 2015) studies. This is because the actual IoT and e-learning integration revolution began after 2014.

This study aims to answer the following research questions: How is IoT used in e-learning systems? To answer the research question, five sub-questions should be addressed to figure out the goals, scope, significance, and future of deploying IoT in the e-learning process, and the future of this emerging technology:

RQ1: What is IoT in e-learning systems?

RQ2: Where is IoT implemented in e-learning systems?

RQ3: How is IoT implemented in e-learning systems?

RQ4: What is the impact of using IoT in e-learning systems?

RQ5: What are Challenges and Future Directions sets of IoT in e-learning systems?

The literature review was conducted by searching scholarly databases; Google Scholar, IEEE Explore, ACM, Springer, MDPI, Wiley, Emerald, and Elsevier. The investigation starts with selecting the topic, analyzing, interpreting, and coming out with the research problem. A range of search phrases and their variations were used to conduct thorough searches including: "e-learning" OR "e-learning" OR "smart learning" OR "smart class" OR "smart teaching" OR "virtual learning" OR "virtual study" OR "virtual class" OR "online learning" OR "online class" OR "online study" OR "online teaching" OR "online tutoring" AND IoT OR internet of things. The focus of this study is on the present state of e-learning and IoT integration. As a result, the following inclusion criteria were used: IoT must be incorporated into the construction, architecture, design, or modeling of e-learning. There should also be proof of deployment (for example, a description or presentation of the actual implementation, or proof of model assessment). Based on the criteria for inclusion, the searches turned up 40 items. Of those, 28 were journal articles and 12 were conference articles. The papers included in this work are depicted in Table I.

Fig. 2. Research methodology.

V. FINDINGS

This section provides a comprehensible overview of applying IoT in e-learning systems. The paper discusses some questions related to IoT and e-Learning systems and how they have been explained and answered in several previous studies. Table I summarized the related work and simplified and clarified the research questions. The answer to each question can be yes or no, which was designated '✓' inclusion in the study and '----' for not implicitly included.

TABLE I. PREVIOUS FINDINGS

Ref	Research Questions				
	RQ1	***RQ2***	***RQ3***	***RQ4***	***RQ5***
[23]	✔	----	----	✔	✔
[26]	✔	✔	✔	----	----
[80]	✔	----	✔	✔	✔
[81]	✔	✔	----	✔	----
[24]	✔	✔	✔	✔	----
[49]	✔	✔	✔	✔	----
[64]	✔	✔	✔	✔	----
[82]	✔	✔	----	✔	✔
[63]	✔	----	----	✔	----
[83]	✔	✔	✔	----	----
[84]	✔	✔	----	----	✔
[66]	✔	----	✔	✔	✔
[56]	✔	----	✔	✔	✔
[69]	✔	✔	----	----	✔
[85]	✔	✔	----	----	✔
[74]	✔	✔	----	----	----
[14]	✔	✔	✔	✔	✔
[40]	✔	----	----	✔	✔
[71]	✔	----	----	✔	✔
[20]	✔	✔	✔	✔	----
[73]	✔	✔	✔	✔	----
[67]	✔	✔	✔	✔	----
[16]	✔	✔	✔	✔	✔
[37]	✔	✔	✔	✔	✔
[19]	✔	✔	✔	✔	✔
[21]	✔	✔	----	✔	----
[11]	✔	✔	✔	✔	✔
[41]	✔	✔	✔	✔	----
[10]	✔	✔	✔	✔	----
[17]	✔	✔	✔	✔	✔
[39]	✔	✔	----	✔	----
[18]	✔	----	✔	✔	----
[27]	✔	----	----	✔	----
[15]	✔	✔	✔	✔	✔
[86]	✔	✔	✔	✔	----
[87]	✔	----	----	✔	✔
[13]	✔	✔	----	✔	----
[4]	✔	✔	✔	✔	✔
[88]	✔	✔	✔	✔	✔
[22]	✔	✔	✔	✔	----

A. RQ1: Internet of Things (IoT) in e-Learning Systems

The integration of new technology such as the IoT in e-learning systems is a practical example of providing different smart services [37] for enhancing the learning process, achieving better outcomes, and decreasing cost and time [22, 41]. IoT is the main supporter of the smart learning (e-classroom) environment via connecting physical and virtual objects, which makes it more scalable and efficient [10]. IoT has changed conventional e-learning and taken it to an advanced level. Individual skills and knowledge are the results of this advancement [11].

e-Learning equipped with IoT may support and facilitate collecting and sharing notes between learners from the learning classroom through applications, smart devices, and network connections [16, 18, 19]. The use of the IoT with e-learning systems simplifies the learning process [39]. IoT in e-learning systems using IoT may result in fast accessibility, hyper-connectivity, good sharing, personality services, and a sustainable learning environment [13]. IoT e-learning does not only mean enhancing the learning process, it also changes the academic infrastructure and adds new subjects and essential concepts to computer science [89]. The e-learning system developed by the IoT has a global characteristic. The advanced system stores enormous amounts of information and performs a great number of equivalent operations [15]. In terms of awareness, the learner is regarded as the most important factor. For learning arrangement and connectivity, his/her relief, contentment, and encouragement are significant [17].

B. RQ2: Applying Internet of Things (IoT) in e-Learning

Online learners and teachers are connected to the internal learning system and global objects through IoT technology, which enables learners to access enormous pedagogical resources [65, 71]. IoT has some good qualities, such as high-quality association between objects, high-quality access, network communications integrations [10], and the ability to add and remove objects from the connection structure [83]. The IoT has the capability of connecting people to people, people to things, and things to things [14]. IoT devices are used in e-learning to deliver and receive information and directions. The benefits of adopting IoT in e-learning include helping to motivate superior lesson ideas, construct safe facilities, monitor important resources, improve data access, and many others [51]. The IoT can be viewed as a novel approach to managing the educational process through the use of developed technologies. The IoT is used in many e-learning tools, such as interactive learning, smart digital boards,

teaching apps for smartphones, laptops, and tablets, systems that track attendance, digital materials, and many other learning tools like Google Apps.

The implementation of IoT and e-learning has been applied in many fields, such as schools, universities, online training, online certificates, and so on. This is especially critical during circumstances where the disease infection is a threat as the substitution of a face-to-face approach is necessary. For instance, Encarnacion, et al. [48] argued that instructors of physical training may utilize smartphones, smartwatches, and the programs they have on them as effective teaching tools. Sportspeople can enhance their athletic performance using these phones and applications, and students can monitor their movements and gain knowledge about physical education [90]. In higher education, Abd-Ali, et al. [64] reported that IoT implementation in e-learning has enhanced the e-learning process and outcomes through smart coursework utilizing the latest methods in the classroom setting, smart labs to run tests more efficiently and enable tests, including the use of gadgets to enhance student communication with the classmates and teachers, and also scientific content. The same has been reported by Perales, et al. [67] that an online lab that delivers experiential learning through the use of engineering experimental tools has assisted students with their lab instructions and enabled shifting from one online working space to another, easily. Moreover, Sabagh and Al-Yasiri [68] recommended using a context-aware system to capture a vast amount of data about the learner's surroundings, which would be an effective strategy for improving learning. In general, the effective implementation of IoT with e-learning has to consider several factors [14, 48]:

- Learner-oriented approach: The first stage in creating a successful e-learning system is to undertake a comprehensive analysis of learners' needs and the conditions in which they live.
- Productive learning processes: In the modern world, learning materials are increasingly individualized and focused, blurring the lines between learners' personal and professional lives.
- Organizational culture: Because every institution has a unique culture, various working techniques must be taken into account.
- IT capabilities: The foundation of the environment conducive to e-learning is smart IT. It requires certain technology (e.g., smartphones, smart TVs, smart pens, etc), software and applications (e.g., Zoom, Microsoft Teams, etc), and interface components, which form the basis of cognitive data interchange.

C. RQ3: Internet of Things (IoT) Implementation in e-Learning Framework

The IoT network is embedded with electronics, sensors, software applications, and other devices linked to the Internet [22]. These integrated devices are applied in the learning process for improvement [37]. IoT technology uses sensors and smart devices for data collection [19]. The data produced by IoT sensors is transmitted through a network, and the combined data is analyzed via big data analytics [16]. A sensor is something that a learner owns and that is linked to the system. These sensors may be utilized for a variety of educational purposes, including medical training, and genuine learning, using devices like wearable watches, headphones, and smart glasses. How to gauge learners' levels of interest and engagement during e-learning is a challenge when employing IoT e-learning systems. Even though linked learners can use these devices as ways to prove who they are, they can't show proof of engagement until, say, a webcam is running [91]. So, even if in theory these devices might accommodate all learners' needs, their inability to replace face-to-face learning is due to students' lack of engagement. The classroom is equipped with smart devices to create a smart environment that speeds up data fetching and collection [13, 88]. Connecting the information sensing tools and information transformation applications can support the learning process with different students' feedback [14]. In other words, e-learning processes can be improved by constantly monitoring and evaluating what students say about how to make e-learning or the use of IoT devices better. For IoT devices to work together, different types of protocols must be used on the sensor platform [17]. The network infrastructure, communications quality, and improvement of intelligent applications are the three important IoT requirements for achieving smart services [41].

VI. Internet of Things e-Learning Tools

Unlimited communication through the IoT enables learners, teachers, and researchers to work globally [21]. IoT can be used in e-learning systems for various activities to support the learning process [18]. Many of the researchers, such as [16, 17, 19, 37, 88] unanimously agreed that the smart classroom, smart lab, and smart notes are some of the most important and efficient educational aspects to which IoT technology has been applied. Other authors reported other smart activities such as electronic books and attendance tracking [14, 41]. AjazMoharkan, et al. [11] reported other smart tools used in e-learning systems coupled with IoT technology, such as smart digital boards, digital highlighters, Scanmarkers, RFID, and QR. The market continuously provides the e-learning system with IoT smart products that can be combined to achieve new and useful services, as explained in Fig. 3. The following are examples of these tools [11, 80, 85]:

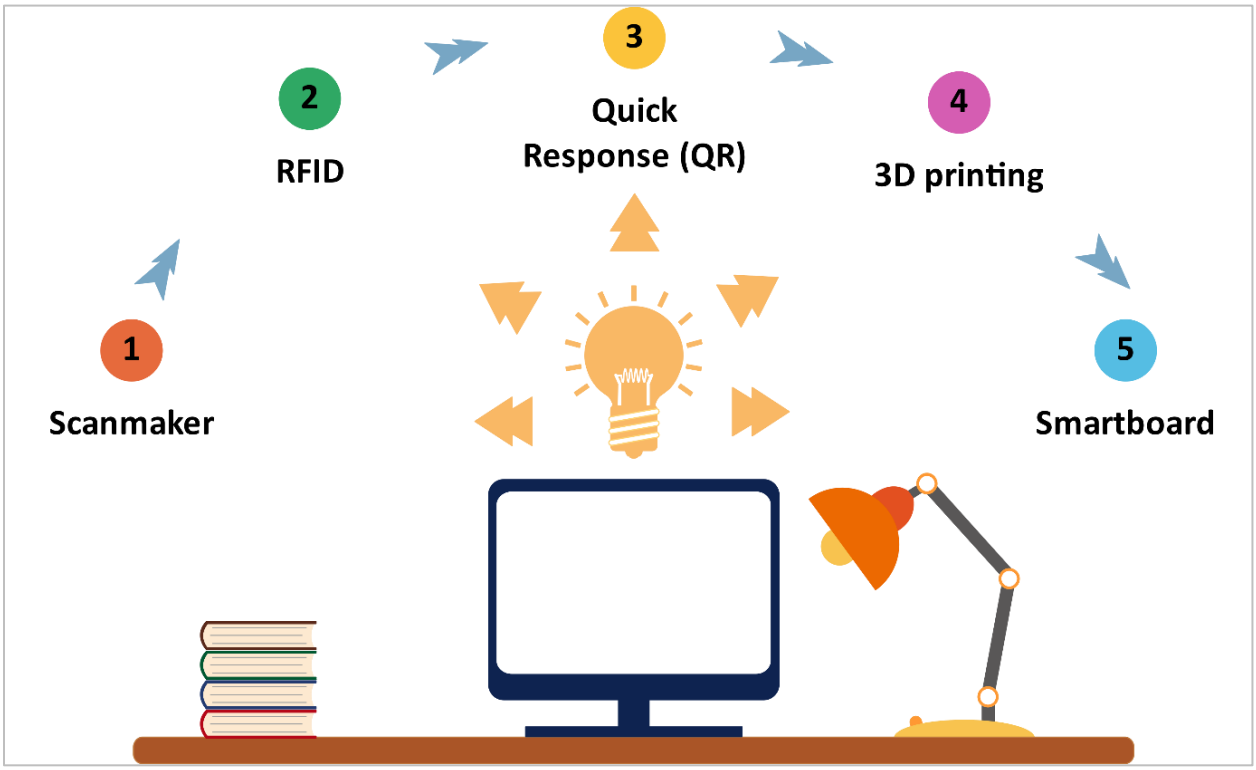

Fig. 3. Internet of Things e-learning tools.

- Scanmarker: The Scanmarker is integrated with a computer or smartphone to convert the printed text to these devices, which makes the process of note-taking easy and fast. Users of Scanmarker are able to scan editable text from books, and other documents into their phone, tablet, or computer in seconds. This text can then be translated into over 40 different languages.
- Learners Attendance using RFID: The presence of students in the classroom is automatically detected by a Smart Classroom-IOT-based device. RFID chips are embedded in the ID cards of students. Every classroom can have an RFID reader that can read all of the students' ID cards at the same time.
- Quick Response (QR): QR code is embedded in books offline work and then linked to online applications. It has the capabilities of quick readability and greater storage capacity.
- 3D printing: Additive manufacturing, also known as 3D printing, is the process of creating three-dimensional solid objects from a digital file. The 3D printer can be linked to a smartphone, tablet, or computer. Through new technology such as 3D printing, developers hope to create more networked products that can sense, collect, analyze, and communicate data.
- Smartboard: enables the teacher and students to work on the same "document" in real-time and share it with the entire class.

VII. Internet of Things E-Learning Architecture

IoT acts as an intermediary between open learning and the classroom [13] and can be used at all levels of learning [39]. Fig. 4 represents the architecture of the IoT technology e-learning system. There are three main layers in this architecture, which are discussed as follows: applications, networking, and sensors [14, 24, 92].

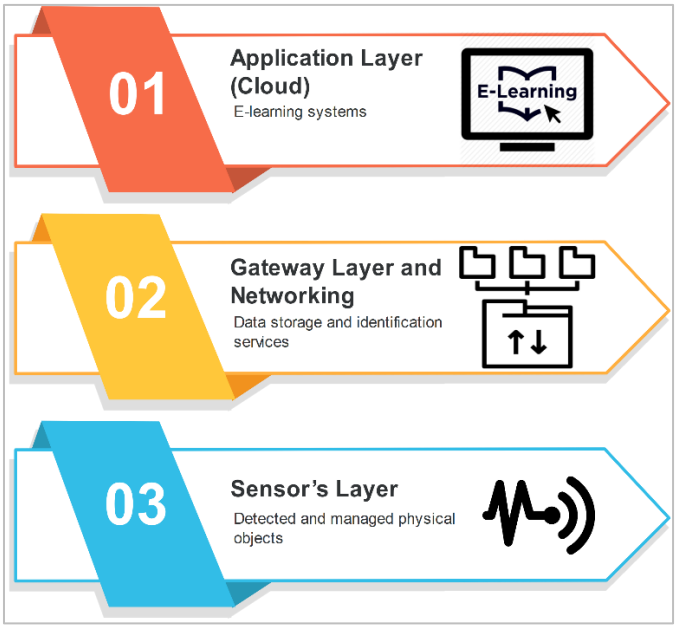

Fig. 4. Internet of Things e-learning architecture.

- Application layer (Cloud): The top layer of the architecture is the application layer, which includes business applications like e-learning systems. These programs can be used to manage and streamline business operations as well as to provide new services. Different types of digital devices communicate with other IoT system components directly. This layer will include all of the services that can be provided to learners and teachers. More information is available in the services area.
- Gateway layer and networking: Data generated by IoT devices is disseminated through this layer. It includes data storage and identification services for related devices, as well as a device management application with access control, administrative, and business capabilities. The IoT gateway is made up of two major components: edge and Fog nodes. Fog nodes, which are equipped with applications, storage, and more processing power than IoT devices, support local processing. As a result, Fog nodes can assist in managing and controlling IoT devices without requiring IoT devices to communicate directly with the Cloud, resulting in reduced time latency. Data from IoT devices are used to support it, and it functions in accordance with that data. The network component's main focus is communication. Based on the data collected by the sensors, the IoT gateway will make the appropriate decision and send the instructions to the actuators.
- Sensor's layer: This layer contains messaging, virtualization, and other components. This primarily consists of detected and managed physical objects relevant to IoT applications as well as learners and teachers. This layer consists of sensors and actuators. Teachers and students interact with the e-learning system using technology such as smartphones, tablets, computers, or more specialized devices. These devices will have a unique user interface that will enable e-learning and effectively guide or support the user.

VIII. Internet of Things e-Learning Entity Model

Both learners and teachers communicate via a network using IoT devices that utilize sensors and actuators to interact with the real environment. Sensors detect a physical entity's features and transform them into digital data that can be interpreted by humans. For instance, an IoT audio sensor can measure how loud the noise is, and the system will respond based on this information. Actuators use digital instructions to operate on or affect the attributes of physical things. As shown in Fig. 5, the components of IoT object e-learning are as follows [24]:

1) Learner unit: A learner is a real-world object that IoT devices manage and perceive.

- Learner portfolio: This component will store the learner's preferences, history, as well as the student's strong and weak aspects, so that it may be considered in order to enhance the learner's level.
- Awareness module: The goal of this unit is to give appropriate services to the learner in light of the circumstances. It is a key notion in distributed network computing. Data may be collected in context-aware systems utilizing small resource-constrained devices like smartphones, PDAs, wireless sensors, and other linked objects. This gives better awareness of the context of service and user demands, allowing for more efficient user assistance.

2) Teacher unit: The second real-world object is the teacher. This unit refers to a variety of things that may be added to both learner and teacher terminals to help in tracking and identification.

- Identification: The purpose of this unit is to determine the identity of the user, availability, and status. For example, this module will identify if a learner spends too much time on one slide throughout revision. In this scenario, he is having difficulty comprehending this slide, thus an alert will be issued to the student to see whether he requires further activities or assistance.
- Assessment: This unit sends out messages to learners informing them of upcoming tests and evaluations.

3) The operation unit: Operation (i.e., operation and application systems) includes different functions such as monitoring and administering units that enable operators to manage the IoT systems' overall functionality and optimize the overall performance of the systems.

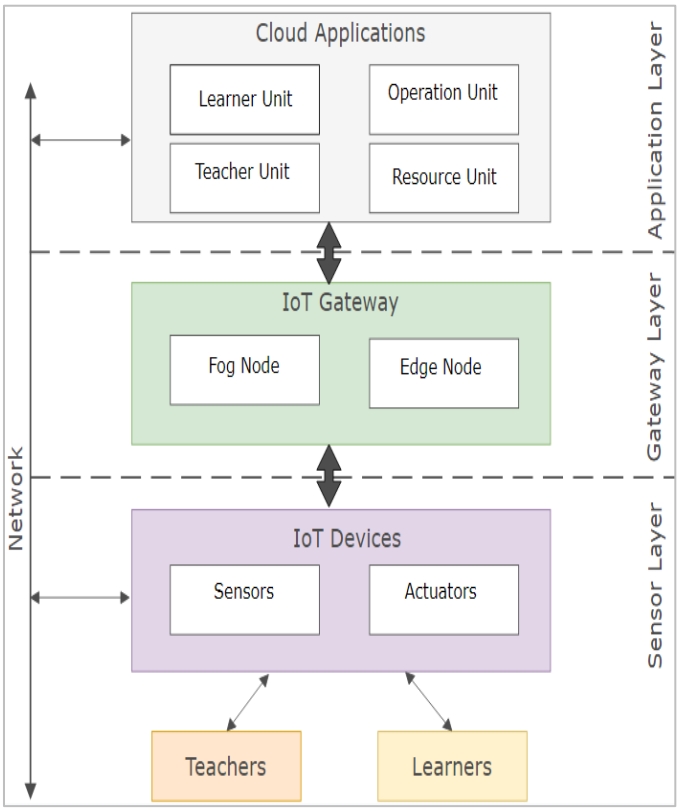

Fig. 5. Internet of Things e-learning system entity model.

4) Resource unit: It includes the regulated endpoints that provide services to IoT system participants who interact with each other and the peer system via their devices. It allows them to have access to the capabilities of the IoT system.

- Material: The course materials will be contained in this unit. The teacher will keep it up to date. It will give pupils sufficient materials.
- Support: The goal of this unit is to give support to learners whenever they require it.

A. RQ4: The Impact of Implementing Internet of Things (IoT) in e-Learning Systems

One of the most significant effects of utilizing IoT in e-learning is the expansion that results from linking learning environments with each other. The interconnection is between the learning parties and also between the different learning environments [37]. IoT in e-learning changes the learning process and enhances performance [82]. Accessibility and collaboration are the most important benefits that learners gain from integrating this technology with e-learning systems [21, 22]. Accessibility improves data sharing speed, note delivery costs, and self-skills [19, 88]. Achieving revolutionary technological development lowers the failure rate of e-learning recipients and professionals [16]. IoT e-learning applications can offer modern inventions and ways to upgrade learning activities. It provides effective participation and helps e-learners integrate into the learning community. The smart classroom is an essential part of IoT e-learning because it generates smart features that, in turn, create high-quality education [10]. Virtual classrooms let teachers know what their students need to learn and how they want to learn it [39]. This is good for both the students and the teachers. Applying IoT in the learning environment increases the speed of receiving and retrieving information by learners in addition to the quality of teacher performance, helps to suggest an intelligent lesson schedule, and continuously monitors important resources and other activities [14].

Linking IoT to e-learning systems reduces instructors' administrative work and invests time in promoting students' skills and talents [65]. IoT aids in collecting and analyzing a massive amount of data and statistics related to students [18]. Gathering the data from IoT smart objects, with which the learner interacts, produces special files that contain personal information in the e-learning system for each learner [13]. Smart learning helps to acquire knowledge quickly and easily, generate new perspectives and solutions, and inspire a comfortable environment, which may be the pinnacle of creativity and enjoyment for all learners and instructors [41]. The use of IoT e-learning helps to connect anyone with everything at any time and from any location [17]. IoT smart tools have the capabilities of observing, communicating, and converting research into intelligence [21].

IX. Discussion

This paper aims to answer the main research question of how IoT is used in the e-learning process and, accordingly, answer the sub-questions that identify the object, design, and future of IoT in e-learning. The following sub-section discusses the implications of the findings of this paper on both the industry and the research community. Also, the future of IoT in the e-learning process (i.e., RQ5) is discussed.

A. Research Implication

The interest in keeping track of the emergence of new technology is one of the most substantial issues that must be given priority in the field of research because it is the basis for developments in all areas. e-Learning systems are a topic of interest and concern among research societies. This study shows that using IoT technology in an e-learning environment is important and necessary. There may be obstacles to the acquisition of IoT smart devices. Some learners and instructors are accustomed to the old system and their adherence to the traditional method, which is considered one of those complications, however, the urgent need requires more diligence to achieve the objectives. The compass is now heading towards smart learning, and the learner represents the need; thus, it must be directed in the correct direction.

Due to the major impact of implementing IoT technology in e-learning systems, system sustainability must be maintained through the configuration of environment-appropriate equipment. The quality of the Internet is one of the factors behind the success of this technology, so the network structure must be constantly reviewed and maintained. The novelty of technology requires extensive training and comprehensive awareness for all learning parties. Technology has no alternative but better technology, so the pursuit of development is a basic requirement. Meanwhile, a balance must be struck between many connected devices to improve quality and monitoring them and ensuring their safety to achieve the desired results. This study can argue that the learning process has an enormous social role. There are many electronic devices, but they are not currently listed among the IoT devices, and the number of intelligent devices will increase to several billion.

B. RQ5: Challenges and Future Directions of IoT in e-Learning Systems?

Without a strong direction for how diverse "things" and e-learning systems should interact, the area of e-learning continues to grow. As a result, achieving interoperability in future educational experiences powered by the IoT is critical. A lot of challenges, such as access controls, technological and conceptual interoperability difficulties, privacy and security issues, and QoS tracking, must be acknowledged in order to promote smooth interaction and resource sharing among diverse and globally dispersed IoT devices, e-learning systems, IoT devices, software solutions, and users [66]. The identification of the issues of e-learning integration with IoT gives fresh views for academics and organizations, as well as introducing communities from many industries to the present challenges and future potential in this field. This article's review of related work identified five future challenges of e-learning and IoT integration, which are illustrated in Fig. 6, and discussed as follows:

- Privacy and security: Even though IoT technologies are evolving, and a growing number of devices are becoming widespread, security remains a major concern. Devices may be attacked, and present security flaws put people in danger. To safeguard students' and instructors' privacy and security while allowing secure information exchange and handling, more research and design efforts are needed [93]. To create effective and acceptable solutions to address IoT security concerns, a collaborative approach to security will be necessary. Moreover, the IoT's true capacity is contingent on privacy-conscious practices. To generate value, new strategies must be developed that take into account the user's privacy preferences and expectations while also encouraging technological innovation and applications [94]. Quantum computing may enable the development of safe processors soon, paving the way for secure products. Regulations and standards must be developed and executed to guarantee secure data transfer and storage under laws and regulations.

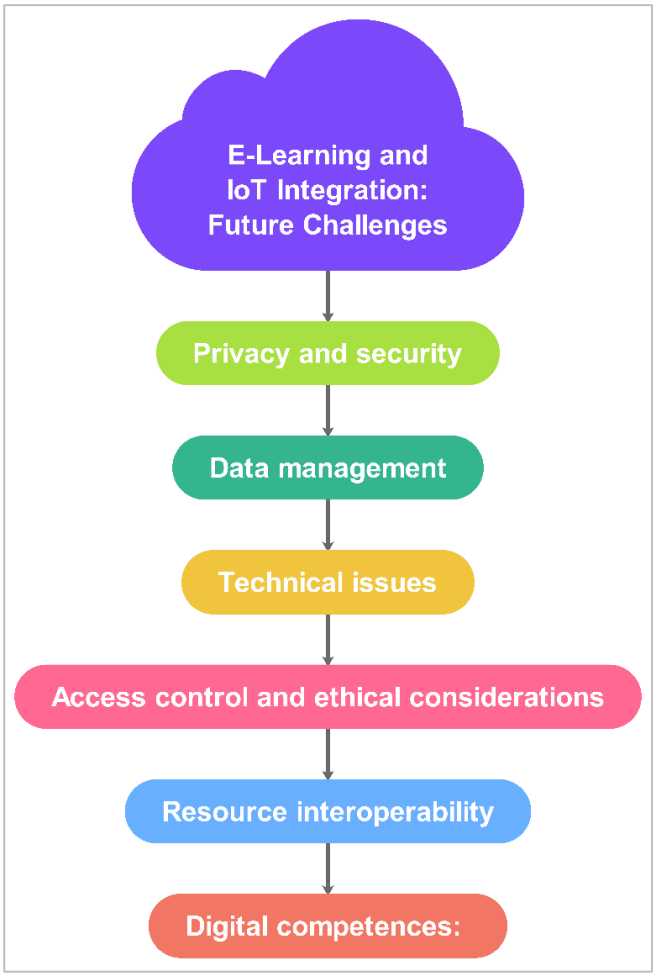

Fig. 6. e-Learning and IoT integration future challenges.

- Data management: The massive volumes of data created by IoT devices have significant prospects for advancing e-learning and citizen life. To improve the learning process, this data can be merged with big datasets and examined instantaneously using new analytics techniques [95]. Nevertheless, there are various issues regarding data ownership accessibility, including the absence of coherent and transparent data ownership legislation. Such issues need further research to be addressed and clear policies to be implemented. Moreover, the massive volumes of data contain a lot of distortion, which makes data analysis difficult. Current methodologies lack the level of resilience necessary, necessitating the implementation of novel data analytics techniques and software tools [78, 95-100]. On the other hand, appropriate visual techniques must be developed in order to acquire meaningful insights into the data collected. Existing methodologies are ineffective when dealing with large amounts of data generated by IoT devices. Information loss, visual distortion, rapidly changing images, huge observation, and high-performance needs are all challenges that need to be handled further.

- Technical issues: Although the IoT provides new options for delivering digital courses, it also poses issues in terms of maintaining instructional quality and evaluating students' work. In order to increase the e-learning quality, new IoT applications and tools are required [101]. Future e-learning systems must offer flexibility and context awareness. Educators and educational organizations can deliver an adaptable learning opportunity by assessing the learners' contextual material. Contextual ontologies, on the other hand, remain a significant difficulty [34]. In future e-learning systems, the software systems, integrated e-learning infrastructures, and "things", therefore enabling e-learning systems to use as few resources as possible [101]. This is extremely difficult given the large number of resources that will be required to create future e-learning systems. This problem might be solved by utilizing and creating techniques for scheduling, optimization, reuse software components and strategic planning as well as the utilization of alternative energy sources [45]. Moreover, several e-learning platforms use hybrid Cloud as their business architecture to host IoT applications. Therefore, communication with the Cloud should be easy and have low latency with such a huge amount of data created from ubiquitous resources.

- Access control and ethical considerations: It is critical to develop suitable ways to control individuals and their privileged access in forthcoming e-learning systems. Providing a person complete control over activities affecting his or her identification, distributed online identity, and multisensory identity are all concepts that should be thoroughly investigated [93]. In addition, the social value of interoperability in future e-learning systems, as well as the possible risks, must be thoroughly investigated. academic institutions, students, instructors, policymakers, and citizens might all benefit from a paradigm that analyzes the technological and ethical limitations of maintaining interoperability in future e-learning systems [101].

- Resource interoperability: In the e-learning context, usually, the emphasis on interoperability is on technological concerns such as data format and communication protocols [101]. However, addressing the factors of organizational and managerial interoperability such as regulations as well as information/knowledge interoperability such as semantics is crucial. The New European Interoperability Framework, which aims to provide the best service and information flow, might be useful for addressing managerial and information interoperability, in future e-learning systems [66]. Moreover, due to the rapid development of technology, researchers and the e-learning industry must continuously pursue and search constantly to find out what is new and useful. The future of IoT will be favorable as long as there is a continuous evolution and thus will affect the future of e-learning and related technology [66].
- Digital competences: The terms "digital competencies" refer to the creation of digital material, data and information knowledge, collaboration and communication, analysis, and problem-solving. To successfully engage in e-learning, learners must possess certain competencies. Several of these competences may be lacking in learners, which can cause a variety of problems, including difficulties with digital creation (such as system design), problems finding and applying digital materials, a lack of analytic capabilities, struggle while exchanging information via modern technology, and are unable to judge the accuracy and worth of information [94].

In the future, learners should have good skills and capabilities to be more competitive. All e-learning parties will gain great benefits through the advancement of their activities, such as the safety of the learning environment, while management, the institutional structure, and the governments may achieve considerable financial benefits and thus importantly contribute to the stability of the educational sector [14]. Future research may extend this study and introduce new technologies to improve the educational sector and resolve related issues.

X. Conclusion

The way services are delivered has changed because of changes in communication technology and the invention and widespread use of IoT devices. Innovations in technology in the field of education make it easier to learn new things and get better at what you already know. e-Learning is one of the most significant systems because it has a great impact on learners, teachers, and the success of the educational process. Adding new technology makes it more effective and attractive. The lack of specific studies in this area encouraged the researchers to concentrate on investigating the previous studies related to integrating IoT in e-learning systems. This paper provides a comprehensive review that includes definition of the IoT e-learning system, the effective impact of utilizing IoT on this system, the advantages of the IoT, the operative tools used to transform learning into smart education and how to use them, and the future challenges and research directions in the context of IoT e-learning integration. This research encourages innovating with modern technologies and applying them in the e-learning process. In the future, researchers and practitioners will be able to focus more on deep research in this field to add new technologies that help improve the e-learning process and open up new opportunities.

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