

**THE INTEGRATION OF INTERNET OF THINGS (IOT) APPLICATIONS IN LIBYAN HIGHER EDUCATION: BENEFITS, OPPORTUNITIES, AND IMPLEMENTATION CHALLENGES****^{1,*}Naser A M Idris, ²Md Gapar Md Johar, ³Ali Khatibi and ¹Ahmed A M El Aribi**¹Post Graduate Center, Management & Science University, Libya²Software Engineering and digital innovation center, Management & Science University, 40100 Shah Alam, Malaysia³Graduate School of Management, Management & Science University, University Drive, Off Persiaran Olahraga, Section 13, 40100 Shah Alam, Malaysia**Received 24th May 2025; Accepted 27th June 2025; Published online 31st July 2025**

Abstract

The rapid development of the Internet of Things (IoT) presents transformative potential for higher education systems worldwide, facilitating more interactive, collaborative, and efficient learning environments. This paper examines the integration of IoT applications in Libyan higher education, highlighting its benefits, opportunities, and implementation challenges. IoT technologies can revolutionise Libyan institutions by enhancing teaching methodologies, streamlining administrative processes, and fostering student engagement. However, adoption faces significant barriers, including inadequate ICT infrastructure, financial constraints, outdated instructional methods, resistance to change, and a lack of regulatory frameworks. The study also explores opportunities, including ICT-driven efforts in Libyan universities, government-driven ICT initiatives, mobile-driven modernisation, and global collaborations. The paper offers actionable recommendations for effective IoT integration through case studies and practical examples, aiming to guide policymakers and stakeholders in building a technologically advanced and sustainable higher education system in Libya.

Keywords: Internet of Things, Higher Education, Libya, Digital Transformation, Smart Campus, Opportunities, Challenges.

INTRODUCTION

Information and Communication Technology (ICT) serves as a transformative force across various sectors, including education, offering improved methods for communication and learning through technologies like cloud computing, big data, and the Internet of Things (Banica *et al.*, 2017; Zhamanov *et al.*, 2017). The COVID-19 pandemic has accelerated the integration of these technologies, highlighting the urgent need for educational institutions to adapt by incorporating electronic platforms to ensure academic continuity. Maatuk *et al.* (2022) claim that the pandemic has demonstrated how much the educational system needs to be improved. According to Kandil *et al.* (2024) and Moridani (2021), the Corona epidemic compelled the education sector to quickly and unexpectedly adopt technology, particularly smart technologies and the Internet of Things. The advent of the Internet of Things (IoT) has revolutionised various industries worldwide, and higher education is no exception. In recent years, there has been a growing interest in leveraging IoT technologies to enhance teaching and learning experiences in academic institutions. With the ability to connect physical objects to the internet and collect data in real-time, IoT devices provide valuable insights that can help improve educational outcomes. The integration of IoT promises significant improvements in teaching and learning practices by enabling smart tools that facilitate immersive and efficient educational experiences (Sakka, 2022; Hassan & Al-Gaddah, 2022; Brown, 2020). It offers solutions for resource management, safety, and personalised learning that are capable of meeting the diverse needs of native digital students. Further, the pandemic has highlighted the need for a technological overhaul in education, compelling institutions to

invest in infrastructure, staff training, and online strategies (Hassan & Al-Gaddah, 2022; Sakka, 2022; Jasim *et al.*, 2021; Siripongdee *et al.*, 2020). In Libya, leveraging IoT can bridge the current educational gaps and foster a responsive, effective system aligned with global standards (Madni *et al.*, 2022; Makhluaf & Abdulshahed, 2020). For Libya's stakeholders, staying abreast of technological advancements and understanding the readiness of individuals and organisations is vital for successful IoT implementation. This transition could position Libya as a leader among developing nations in employing innovative educational technologies, enhancing both educational quality and socio-economic development (Li & Pei, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021). However, while developed nations have effectively implemented IoT in education, resulting in smart campuses that enhance efficiency and learning (Li & Pei, 2022; Moridani, 2021; Maatuk *et al.*, 2022), developing countries like Libya face hurdles, including infrastructure limitations, insufficient funding, a lack of standard policies and a lack of technical expertise (Li & Pei, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021). These issues are alarming; without strategic intervention, Libya risks falling further behind in an education sector that is rapidly digitised worldwide. Despite these hurdles, the opportunities presented by IoT in higher education are vast, ranging from personalised learning experiences to increased operational efficiency. Recently, initiatives by the Libyan government demonstrate commitment to enhancing higher education infrastructure through ICT, aiming to transition from an oil-based economy to a knowledge-driven one (Miles *et al.*, 2021). These efforts include partnerships with technology enterprises to introduce e-learning platforms that educate students in digital skills, preparing them for the evolving market (Al-Mansoori, 2020; Mhamed Alshref *et al.*, 2021; Abied *et al.*, 2021).

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Undoubtedly, a dearth of research exists about the adoption of emerging technologies, namely the IoT, within the Libyan context. The current political climate and limited access to modern technology and suitable infrastructure are expected to slow the country's pace of IoT adoption (Hbaci *et al.*, 2021; Ireda *et al.*, 2019). Therefore, this study aims to analyse the current landscape of IoT in Libyan higher education, exploring the benefits, opportunities, and implementation challenges that come with integrating IoT technologies into academic institutions.

The internet of things (IoT) in higher education

In light of the Internet of Things' transformative role in education as a whole, it is essential to investigate its specific implications for higher education institutions. With their complex structures and diverse needs, higher education institutions present unique opportunities and challenges for the integration of IoT technologies. In accordance with 4IR, higher education institutions (HEIs) are urged to incorporate technology into Education 4.0. The Education 4.0 environment includes a smart campus with dynamic learning, high levels of creativity, conducive classrooms, and ecological technology. Rapid changes in 4IR make it more challenging for higher education institutions (HEIs) to maintain the provision of market-ready skills (Mansor *et al.*, 2020). The adoption of contemporary ICT practices in higher education institutions is not a passing fad. Universities must endure reforms due to the rapid changes occurring in the world, which impact all stakeholders, including students, employers, and faculty (Mkrttchian *et al.*, 2021). As a result of the urgent need to digitalise training and education processes for academicians who lack the innate technical skills required for online education, higher education institutions are undergoing profound transformations. In an era of accelerated change, technological advancements, and digital transformation, the university system must strive to overcome this issue to remain competitive and provide high-quality education (García-Morales *et al.*, 2021). Institutions have therefore been modernising their infrastructure to support smart device programmes that speed up learning and creativity among students (Sapra, 2024).

The integration of internet of things (IoT) in Higher education

Higher education institutions (HEIs) are often vulnerable to changes in governmental directives, social conditions, and technological developments since these factors firmly interfere with their performance (Lašáková *et al.*, 2017). This is the reason HEIs have rapidly grown, altering higher education's character to become more competitive. This fuels the desire to raise the level of services offered through cutting-edge technologies (Chweya & Ibrahim, 2021). As an Internet-based technology, the IoT has significant implications for higher education (Chweya & Ibrahim, 2021). Saeed *et al.* (2021) state that the IoT is a relatively new technology that has taken root in various industries, particularly education systems. The widespread use of this technology is anticipated to result in additional alterations in this area. According to Al-Emran *et al.* (2020), numerous institutions of higher education around the globe adopt the IoT in an effort to generate profound changes in their performance (teaching, learning, management, training, facilities, etc.). The Internet of Things (IoT) spans a variety of disciplines, including computer and information science,

engineering, the social sciences, and mathematics. Bayani *et al.* (2017) assert that the Internet of Things has transformed traditional education elements such as institutions, universities, and students into smart variants (electronic elements). Due to the fact that a significant number of educational institutions are not connected to one another or communicate information, the IoT is better adapted to fill this void. Recent years have witnessed significant advancements in IoT applications across higher education institutions globally, demonstrating transformative potential in campus operations and learning environments. The University of Koblenz developed a smart campus infrastructure leveraging IoT sensors and LoRaWAN technology, enabling real-time monitoring of air quality and energy consumption while optimising HVAC systems through predictive analytics, resulting in enhanced energy efficiency and cost savings (Blazevic & Riehle, 2023). Similarly, the University of Washington implemented an IoT-based environmental control system using thousands of interconnected sensors to optimise HVAC and lighting operations, achieving substantial reductions in energy consumption (Fox, 2020). Arizona State University has pioneered IoT solutions addressing both sustainability and academic needs, including smart faucet systems that reduce water waste in stadiums and virtual beacon programs automating attendance tracking to facilitate early interventions for at-risk students (Fox, 2020).

The University of New South Wales expanded IoT integration through multiple smart campus initiatives, such as automated attendance tracking, real-time space utilisation monitoring, and optimised transportation services (Sutjarittham *et al.*, 2018). Meanwhile, emerging research at Al-Zaytoonah University of Jordan explores IoT's potential to transform assessment systems and digital learning platforms (Derbas *et al.*, 2025). These case studies collectively illustrate IoT's multifaceted benefits in higher education, ranging from operational efficiency and sustainability to enhanced learning experiences and institutional analytics. In China, experimental research utilising RFID and IoT technologies established their effectiveness in fostering interactive learning environments (Tan *et al.*, 2018), while Thailand's implementation of IoT-enabled mobile technologies through affordable tablet PCs improved educational access for disadvantaged rural students (Pruet *et al.*, 2015). Research in the United Kingdom at Harlow UTC revealed IoT's effectiveness as an engaging teaching platform for computer science, particularly in stimulating student interest through educational living labs (Chin & Callaghan, 2013). Similarly, a Colombian study by Gómez *et al.* (2013) demonstrated that IoT-based interaction systems incorporating RFID and NFC technologies facilitated collaborative learning by enabling virtual engagement with physical objects. Practical applications have extended to campus infrastructure, as evidenced by Majeed and Ali's (2018) proposed IoT model for creating smart university campuses featuring intelligent classrooms, parking systems, and educational frameworks. Complementary technological innovations include Arora and Kaushik's (2020) web-based attendance tracking system utilising NFC-enabled smartphones, which automates record-keeping while maintaining accuracy. Collectively, these studies underscore IoT's transformative capacity in education, spanning pedagogical enhancement, operational efficiency, and equitable access across both developed and developing educational contexts.

Benefits of implementing internet of things (IoT) in higher education

Education has changed beyond the limitations of conventional classrooms in the modern digital era. The adoption of technology, especially the IoT, is transforming university operations, facilitating the development of more intelligent campuses. These developments foster environments that are increasingly collaborative, efficient, and sustainable, hence enriching the entire learning experience (Sapra, 2024; Mircea *et al.*, 2021). Several studies highlight the significant potential of integrating Internet of Things technology in higher education institutions. These studies provide an argument for the further investigation and utilisation of IoT technology in various contexts. Research has shown that the implementation of IoT technology is gaining considerable popularity due to the technological, social, and competitive pressures for innovation and transformation (Aldowah *et al.*, 2017; Lee and Lee, 2015; Marquez *et al.*, 2016). According to Sapra (2024), the global IoT in education market is projected to reach \$19.6 billion by 2025, reflecting the growing adoption of smart technologies in educational institutions. Notably, 58% of these institutions plan to increase their investments in IoT solutions, recognising their potential to enhance learning environments. Research indicates that smart classrooms, enabled by IoT, can improve learning outcomes by up to 20% through personalised and interactive experiences. The IoT can create a more interactive and engaging learning experience with smart boards and digital textbooks providing real-time, dynamic content and remote learning. It allows students to access educational resources from anywhere (Kumar & Al-Besher, 2022; Ranganath *et al.*, 2022; Saeed *et al.*, 2021; Shaikh *et al.*, 2021; Chattopadhyay, 2019; Merhad & Wakim, 2018).

Moreover, surveillance systems, access control devices, and emergency notification systems can make campuses more secure (Asad *et al.*, 2022; Safdar *et al.*, 2019; Bagheri & Movahed, 2016). The IoT can also help manage resources more efficiently, including energy, classroom space, and equipment, by utilising systems such as smart energy management and smart classrooms (Ranganath *et al.*, 2022; Safdar *et al.*, 2019; Bagheri & Movahed, 2016; Benson, 2016). Sapra (2024) asserts that among the most immediate advantages of IoT implementation are substantial cost savings that colleges can attain through automation, energy optimisation, and better resource management. Furthermore, the IoT devices can collect a vast amount of data that can be used in research projects across various disciplines. Additionally, the IoT can monitor the health and wellbeing of students and staff, particularly in response to health crises (Banica *et al.*, 2017; Asseo *et al.*, 2016; Takpor & Atayero, 2015). Predictive maintenance of physical infrastructure can be facilitated by the Internet of Things (IoT), alerting staff to potential issues before they become serious problems (Sapra, 2024; Negm, 2022a; Saeed *et al.*, 2021; El Mrabet & Moussa, 2020). Finally, IoT-driven smart solutions are essential in advancing sustainable practices on university campuses, enabling institutions to achieve their environmental objectives and support green initiatives. However, it is essential to recognise that while the Internet of Things can provide these valuable benefits, its implementation also poses numerous challenges (Mircea *et al.*, 2021; Al-Emran *et al.*, 2020; Letting & Mwikya, 2020; Kassab *et al.*, 2020; Safdar *et al.*, 2019). To ensure successful implementation, it is necessary to develop logical and efficient solutions, for instance, reliable internet

infrastructure, robust cybersecurity measures, and well-planned training and development programmes for faculty, staff, and students to prevent any resistance to change that could potentially impede the implementation of Internet of Things technology. Despite these challenges, the transformative potential of the IoT should not be overshadowed. As research continues on the topic of higher education in Libya, it is important to consider how technological advancements may intersect with the unique opportunities and challenges Libyan institutions face. The potential for the IoT to transform the landscape of higher education in Libya, as it has done globally, is an interesting possibility that merits in-depth investigation.

Higher Education in Libya

Higher education in Libya has encountered significant transformations over the years, shaped by the country's historical, political, and social contexts. As Libya continues to navigate the complexities of post-revolutionary recovery, the higher education sector faces both considerable challenges and unique opportunities. The current higher education system in Libya is characterised by a combination of public and private institutions, the majority of which are state-funded universities. As an emerging economy, Libya's educational institutions are in a period of transition, striving to adapt to global technological advancements and incorporate these into their instructional and operational procedures (Senusi, 2023; Al-Mansoori, 2020). Universities and colleges across the country are increasingly recognising the need to shift from traditional pedagogical methods to those that emphasise technology to stay competitive and relevant (Obaid *et al.*, 2021; Elabbar, 2021; Ericsson, 2021; Hbaci *et al.*, 2020; Saleh, 2020). However, as studies pointed out, while the benefits of IoT are numerous, implementing it in the higher education sphere can present its set of challenges, particularly in a developing country like Libya. Thus, to navigate these obstacles and fully realise the potential of IoT, it is still crucial to comprehend the specific context of higher education in Libya. The history of higher education in Libya dates back to the mid-20th century; in December 1955, King Idris I of Libya issued a royal decree establishing the University of Libya in Benghazi. This event is regarded as the beginning of the annals of the Higher Education (HE) System in Libya. This directive elucidated in greater detail the objectives for the establishment of additional institutions. In 1973, after a period of time had passed, the Libyan University was separated into two universities, Benghazi and Tripoli, as a manifestation of this direction. According to data provided by the Tempus project of the European Commission in 2016, the number of universities and institutes for higher technical and vocational education in Libya has increased continuously since 2016 (AlBarhami, 2022; Al-Ashhab & Al-Ashhab, 2022; Elkhoully *et al.*, 2021; UNIMED, 2020; Rhema, 2018). Currently, the higher education system in Libya consists of 26 public universities located throughout the country, 8 accredited private universities, and technical and vocational schools, all of which are administered by the Ministry of Higher Education and Scientific Research through a dedicated board. The number of universities has steadily increased over the past decade (Ministry of Higher Education and Scientific Research, 2023; MEDirections, 2022). In 2004, approximately 200,000 students were enrolled in universities, while 70,000 were enrolled in vocational institutions. Increased government involvement and free education led to growth, with private universities adding

new momentum (Elbeshti *et al.*, 2022). Libya had 160 faculties in 2016, which had increased to 231 public and 8 private faculties by 2023, thereby expanding the educational system's geographical reach (UNIMED, 2020). The number of students increased significantly, from 341,841 in 2010–2011 to 402,392 in 2020–2021, with the majority of students attending public institutions (AlBarhami, 2022; Al-Ashhab & Al-Ashhab, 2022; Elkhoully *et al.*, 2021; Shafter & Ruth, 2020; Rhema, 2018). By 2021–2022, enrolment reached 464,288, comprising 6.7% of Libya's population, surpassing global averages, which typically range from 2% to 3% of the total population, thereby positioning Libya well above the international average (Specialised Committee, 2023). Higher education in Libya has developed alongside a host of new challenges for decision-makers, academics, students, and society. While it is encouraging to see higher educational institutions develop and attract more students, these trends still have room for improvement (Awgheda & Radwan, 2022). Figure 1 presents a concise overview of the progression of student enrollment within both state and private universities in Libya during recent years.

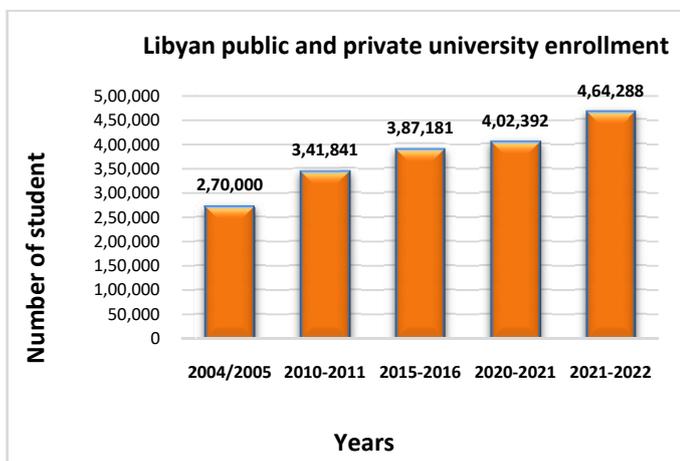


Figure 1. Libyan public and private university enrollment

Challenges facing higher education in Libya

The COVID-19 pandemic prompted a global shift toward digital education, necessitating Libyan higher education institutions to swiftly adapt to unprecedented circumstances. In light of these challenges, the education sector is increasingly regarded as essential for the nation's recovery and long-term prosperity (Ramadan *et al.*, 2019; Almgadmi, 2018). Nonetheless, Libyan higher education continues to grapple with a multitude of institutional challenges that have compromised its operational efficiency and overall effectiveness. Given these challenges, there is a pressing need for a comprehensive reassessment of higher education structures and pedagogical approaches. Such reform is essential to closing the gap between academic output and the evolving demands of the labour market (Awgheda & Radwan, 2022).

a) Inadequate ICT Infrastructure

The inadequate ICT infrastructure and financial constraints in Libyan higher education institutions provide significant challenges to achieving educational quality (Idris *et al.*, 2023; Ghawail *et al.*, 2021; Gadour, 2021; Salman & Soliman, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021). Several universities continue operating outdated facilities that lack

necessary modern equipment, operational libraries, and well-equipped laboratories—resources vital for successful teaching and significant research. This deficiency negatively impacts student learning environments and the academic advancement of faculty members (Ghawail *et al.*, 2021; Gadour, 2021; Salman & Soliman, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021). Furthermore, several scholars claim that inadequate ICT infrastructure—defined by limited network coverage, unreliable internet connectivity, and insufficient access to educational software—hinders the implementation of e-learning and digital education. Numerous institutions encounter difficulties including inadequate servers, elevated internet expenses, and insufficient technical help (Almansuri, 2024; Almansuri & Elmansuri, 2015).

b) Rising Enrolment in Libyan Higher Education

The enrolment trends in Libyan higher education reveal that a younger generation is actively looking for educational opportunities, with a growing number of students pursuing higher education degrees. Nevertheless, substantial demographic disparities continue to exist, as education access varies notably between urban and rural areas, as well as across socio-economic categories. The quality of education has frequently been compromised as a result of the significant strain that the rapid increase in student numbers has placed on universities and colleges, which have been forced to stretch their facilities, faculty, and resources to the limit (Rhema, 2018; Shafter & Ruth, 2020; Al-Barhami, 2022; Al-Ashhab & Al-Ashhab, 2022). This growth has presented significant challenges, particularly for large institutions in Tripoli and Benghazi, which now accommodate approximately 100,000 students each, well beyond their intended capacity (ICEF, 2014; University of Benghazi, 2023; University of Tripoli, 2023; uniRank, 2023). Although the increasing enrolment rate is a positive development, it also places additional pressure on existing institutions to address overload. In order to guarantee equitable access to quality education, it is imperative to implement innovative solutions (Specialised Committee, 2023; Rhema, 2018; Shafter & Ruth, 2020; Al-Barhami, 2022; Al-Ashhab & Al-Ashhab, 2022).

c) Financial Constraints

Financial constraints increase the challenges encountered by Libyan higher education institutions, significantly hindering their ability to invest in essential enhancements and routine maintenance, thereby adversely impacting the overall quality of education delivered (Idris *et al.*, 2023; Ghawail *et al.*, 2021; Gadour, 2021; Salman & Soliman, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021). Funding deficiencies hinder growth in infrastructure and the enhancement of academic programmes, limiting investment in modern educational facilities and innovative technologies essential for effective teaching and research. The failure to provide adequate salaries further reduces efforts to attract and/or keep qualified academic staff. Consequently, numerous institutions rely significantly on governmental funding and international aid to maintain their fundamental operations (Qabas Co, 2025). Furthermore, constrained financial resources have hindered the effective implementation of e-learning and remote education, mainly due to inadequate digital platforms and insufficient technological investments (Ghawail *et al.*, 2021; Gadour, 2021; Salman & Soliman, 2022; Maatuk *et al.*, 2022; Busneneh & El-Bazzar, 2021).

d) Outdated Instructional Methods

Libya continues to face challenges associated with traditional face-to-face teaching and learning methods within its higher education environment (Ramadan *et al.*, 2019). Dependence on conventional approaches limits educational flexibility and hinders innovation, limiting institutions' ability to respond to evolving educational demands (Busneh & El-Bazzar, 2021; Putjorn *et al.*, 2015). Educational practices remain heavily theoretical-based systems, emphasising memorisation and rote learning rather than fostering critical thinking or practical skills. This has resulted in a significant gap between academic education and the professional skills demanded in the labour market, leaving numerous graduates inadequately prepared (Altaeb, 2021). Moreover, numerous educational institutions lack access to international academic journals, online databases, and modern laboratory facilities, thereby further restricting both students and faculty from participating in current research and global academic discourse (Elkhouly *et al.*, 2021).

e) Absence of Regulatory Frameworks

The Libyan Ministry of Higher Education's 2023 report highlights a significant lack of well-defined policies and regulations governing higher education and scientific research, which continues to hinder advancement in the sector. The absence of explicit guidelines poses challenges to modernisation initiatives. Furthermore, the national higher education policy highlights a considerable deficiency in statistical data and comprehensive empirical research, hindering the development of evidence-based policies (Sawahel, 2024). Although there is a demand for expert contributions to address these gaps, the integration of such recommendations into actionable regulations remains in progress. The UNIGOV Project Report (2016) similarly underscores the lack of clear regulatory frameworks and governance structures as a key obstacle to sustainable development in Libyan universities. It emphasises the necessity of revising higher education legislation to align with the current socio-economic and political landscape, as well as establishing quality assurance frameworks and fostering institutional autonomy. The report highlights the lack of current regulation regarding research and technology transfer as an important barrier to fostering competitive research in higher education institutions (UNIGOV Project Report, 2016). Further, Elkhouly *et al.* (2021) point to outdated policies and the lack of a national accreditation body as contributing factors to inconsistencies in academic standards and institutional performance. The unregulated growth of private universities is also cited as a concern. Ayub *et al.* (2016) assert that political instability and the absence of centralised governance have further disrupted regulatory continuity in Libya's higher education system.

f) Resistance to Change Among Stakeholders

Alongside technical and institutional barriers, resistance to change among key stakeholders remains a significant challenge within Libyan higher education. Faculty, administrators, and policymakers frequently resist shifts toward digital or innovative educational models, often due to entrenched traditional practices (Mohamed, 2024). A significant number of faculty members depend predominantly on face-to-face education and might be deficient in training or

motivation to adopt modern pedagogical methods and digital tools (Elkhouly *et al.*, 2021). The academic culture, especially in systems with tenure, often grants faculty a high degree of autonomy. While this supports academic freedom, it can also create resistance to top-down reforms that require changes to long-standing teaching methods (Anderson, 2023). In Libya, university governance structures tend to be decentralised and consensus-based. While this approach encourages inclusivity, it can also hinder timely decision-making and weaken change efforts, particularly when stakeholder interests conflict (Anderson, 2023). Some academic staff view the adoption of new technologies or institutional restructuring as a threat to their roles or a demand to acquire unfamiliar skills, fostering hesitation or outright resistance (Horvath, 2024). Furthermore, limited financial and technical resources common in many developing countries can prevent institutions from effectively implementing reforms, even when there is willingness to do so (Horvath, 2024). Resistance is also shaped by psychological factors; change can provoke anxiety, denial, or even active opposition (Horvath, 2024). External pressures, including political interference, public doubt, and media criticism, can render institutions more defensive, particularly when changes are considered as externally imposed by governmental or business groups (McNaughton & Rosenberg, 2025; Specialised Committee, 2023). Overall, addressing these multifaceted challenges requires concerted efforts by policymakers and stakeholders to reform and modernise Libyan higher education, ensure it meets international standards, and effectively contribute to the nation's development. Furthermore, overcoming these barriers is not only essential for improving educational quality but also for unlocking the transformative potential of emerging technologies such as the Internet of Things in Libyan higher education institutions. To achieve this, collaboration with government agencies, industry partners, and international organisations could help overcome these obstacles and create more IoT-friendly environments at universities across Libya. By adopting a forward-looking framework, Libyan higher education can transition toward a more resilient, innovative, and globally competitive system one that meets both current demands and future challenges. Opportunities for Improving Higher Education in Libya.

Opportunities for improving higher education in Libya

Libya's academic institutions possess significant untapped potential for growth and innovation. Enhancing quality necessitates addressing organisational inefficiencies and adopting digital transformation strategies. Research by Kenan *et al.* (2015) confirms that improving higher education necessitates a strong focus on Information and Communication Technology (ICT), particularly in educational management, administration, and teaching processes. Furthermore, Elnajar *et al.* (2019) emphasise the growing need to integrate emerging technologies in higher education not only to meet students' evolving needs but also to ensure high-quality education and equip them with skills for modern challenges. Consequently, there are potential opportunities to improve higher education in Libya, and it is crucial to highlight these opportunities.

a) ICT-Driven Higher Education Initiatives in Libya

Libya's higher education institutions are increasingly prioritising international standards and competing with global institutions. This shift is crucial for transitioning to a knowledge-based society, where ICT is indispensable (Kenan

et al., 2015). Recognising this necessity, many Libyan Higher Education Institutions (LHEIs) have adopted e-learning as an innovative approach to enhance learning and teaching outcomes (Mohamad *et al.*, 2018). Efforts are underway to modernise academic processes and embed ICT within an educational framework (Ireda *et al.*, 2019). For instance, the University of Nalut has established e-learning platforms, provided official university email systems, and implemented a digital archiving system for academic documents, serving as a pioneering model of digitalisation among Libyan universities since its founding in 2017 (Alajeel, 2025). Further, Sebha University continually improves its technical and technological infrastructure by supplying necessary equipment and devices that enhance the institution's effectiveness. It is also developing electronic units for students in academic departments and offering e-learning solutions, including computer laboratories and virtual classes (Strategic Plan Team, 2022).

a) Government-driven initiatives in libyan higher education

Libya is making impressive strides in upgrading its higher education system. The Libyan government has launched a number of initiatives and agreements to upgrade the infrastructure of higher education institutions, with a particular focus on incorporating information technology. These initiatives and agreements are part of a concerted effort to make sure that Libyan students have access to the highest quality of education and resources. Supporting this progress, the Libyan Ministry of Higher Education's 2023 report highlights advancements in educational and research initiatives, particularly in educational administration and advanced technology integration (Specialised Committee, 2023). The Ministry of Higher Education and Scientific Research has recently partnered with a leading telecom and technology enterprise (Al-Madar Al-Jadeed Company) to benefit from Al-Madar's cloud services as the first step towards developing and strengthening the capabilities of the higher education sector in order to keep up with the development cycle through the adoption of ICT technologies (Afrigate News, 2021; Alwasat Gate, 2021; Senusi, 2023). Hence, the ministry's present objectives emphasise providing institutions with the tools and mechanisms needed to cultivate a skilled workforce capable of building a knowledge-based economy and ensuring comprehensive prosperity. This vision aligns with the strategic framework for higher education and scientific research (2024–2034), which emphasises the necessity of developing advanced systems that deliver high-quality services and cutting-edge scientific outputs (Sawahel, 2024). Such progress will enable Libya to keep pace with global advancements and build a distinguished future (Specialised Committee, 2023). The Libyan government is actively supporting these reforms, aiming to rebuild the education system and promote e-learning (Albarki *et al.*, 2023; Ghawail *et al.*, 2021; Alshref *et al.*, 2021). The government's commitment to these initiatives reflects Libya's dedication to the enhancement of its higher education sector and its determination to provide its students with the best learning environment possible (Saleh, 2020; Al-Mansoori, 2020). Notably, during the COVID-19 pandemic, the government took urgent measures to ensure educational continuity by adopting remote teaching methods (Saleh, 2020).

b) Global-Led ICT Modernisation in Libya's Higher Education

Libya is collaborating with UNESCO on an ICT initiative to upgrade Local Area Networks (LANs) in universities and modernise the Learning and Higher Education Systems (LHES) (Ghawail *et al.*, 2021). A proposed national IT resource centre aims to standardise student information systems and further streamline education management. The pandemic, in particular, accelerated the shift to online learning, leading to widespread use of digital platforms in Libyan universities (Aljad, 2023; Busneneh & El-Bazzar, 2021; Maatuk *et al.*, 2022). Further, Ericsson and LPTIC are collaborating to introduce the Ericsson Educate learning programme to Libya and teach university students digital skills. A large number of students will have access to courses on 5G networks, the IoT, data science, automation, AI, and machine learning via an e-learning platform. Ericsson specialists will host webinars about emergent and next-generation technologies. The programme enhances students' ICT skills and supplements their technical education to prepare them for careers in telecom and ICT (Ericsson, 2021). This rapid adoption demonstrates the potential to transform technology in education. Moreover, the Youth Employment in the Mediterranean (YEM) UNESCO Country Factsheet highlights numerous initiatives aimed at improving computer literacy among young individuals. The "Toyota Discover Your Talent Programme" is a significant initiative, comprising a three-month training course offered thrice yearly since 2018. This initiative is implemented in partnership with Toyota, the United Nations Development Programme (UNDP), and the National Board for Technical and Vocational Education (NBTVE), which operates under Libya's Ministry of Higher Education and Scientific Research (UNESCO, 2024). Indeed, the Libyan government recognises ICT as a key driver for long-term economic and societal success (Hassan & Jamaluddin, 2016).

c) ICT-Driven New Generation of Libyan Learners

Another crucial aspect of this landscape is the new generation of learners. These individuals display proactive behaviour and show increased dependence on the Internet for knowledge acquisition. They like to access information at their convenience, regardless of time or location (Anderson, 2018). The traits of new generations of Libyan learners present a significant opportunity for improving higher education in Libya through several key factors. Initially, younger generations possess a heightened awareness of international educational standards. Their expectations for modern, technology-driven learning environments are driving institutions to evolve (Kolikant, 2010; Levin & Arafah, 2002). Secondly, increased familiarity with digital tools and online learning platforms has led younger students to advocate for blended and e-learning solutions. This transition is progressively diminishing dependence on antiquated pedagogical frameworks and broadening access to global academic resources (Hbaci *et al.*, 2021). Third, newer generations have a greater propensity for research-orientated learning, critical analysis, and entrepreneurial endeavours. This perspective promotes partnerships with global universities and motivates Libyan institutions to enhance their research initiatives.

Finally, young learners are increasingly assertive regarding the necessity for academic autonomy, revised curricula, and faculty advancement. Their activism is compelling policymakers to enact reforms that correspond with global higher education trends (Vogels *et al.*, 2022; Anderson & Jiang, 2018; Hbaci *et al.*, 2021). The advent of emerging technologies and shifts in societal behaviour, especially among the younger generation, require a reevaluation of educational approaches in higher education institutions. Therefore, it is essential to promptly initiate a transformation of existing educational paradigms to include emerging technology and the evolving behaviours of contemporary generations in these instructional approaches (Kar *et al.*, 2021). The present generation of young individuals, who are pursuing higher education, exhibits unprecedented levels of technology literacy owing to their early exposure to mobile devices and continuous access to the Internet, including social networks and other digital platforms (Kuleto *et al.*, 2021; Kar *et al.*, 2021).

d) Mobile-Driven Modernisation of Higher Education in Libya

Mobile learning, often known as m-learning, refers to the use of mobile devices such as smartphones and tablets for educational purposes. Mobile devices dominate in modern technologies (Jouicha *et al.*, 2022). More than fifty percent of academic students use their mobile phones to access course materials and lecture notes (Ahmed *et al.*, 2022e; Stephens *et al.*, 2021; Hasan *et al.*, 2024). They enhance e-learning by increasing the accessibility of mobile phones; hence, they simplify and facilitate the pursuit of higher education. Mobile phones have facilitated e-learning, enhancing its accessibility and efficiency regardless of place or time (Ahmed *et al.*, 2022). In developing nations, the proliferation of mobile phone usage has rendered these devices essential for educational accessibility (Rhema & Sztendur, 2013). In Libya, the rapid expansion of mobile technology acts as a transformative force in higher education, bridging infrastructural gaps and expanding access to learning. Mobile phones are more reliable and cost-effective than infrastructure-intensive technology for communicating with students. Smartphones and tablets are enhancing connectivity and technological proficiency among Libyan youth (Alhadad & Ertürk, 2019; Rhema & Sztendur, 2013). Hammoud (2023) asserts that high-speed internet in Libya enables many individuals to utilise smart devices and mobile phones. This is supported by the ongoing development and implementation of advanced mobile networks in Libya, which include the restoration of 4G coverage in numerous regions and the preparation for the deployment of 5G infrastructure. This infrastructure will enable the provision of ultra-fast broadband and seamless high-speed mobile internet access. These infrastructure enhancements enable the improved use of mobile technologies and smart devices in both urban and rural areas, thereby reducing the digital divide and creating new opportunities for mobile applications and services (Abdalla, 2024). Idris *et al.* (2023) report a substantial rise in mobile phone usage among younger generations in recent years. The prevalence of mobile phones in Libya increased from 1% in 2001 to 171% in 2010, signifying several subscriptions per individual (Sanou, 2012). Libya mitigated infrastructural deficiencies with mobile broadband. In 2010, the nation had 10.9 million mobile-cellular users and 2.7 million mobile broadband subscribers, as reported by Sanou (2012). Global Digital Insights forecasts that the majority of Libyans will be online by 2022. GSMA Intelligence reported

that in 2022, 11.87 million Libyans possessed cellular mobile connectivity, or 169.6% of the population. From 2020 to 2022, mobile connections rose by 244,000, representing a 2.1% gain. In January 2023, Libya recorded 12.05 million active mobile phone connections, representing 175.9% of its 6.85 million population. From 2022 to 2023, Libya experienced an increase of 2.1%, equating to 245,000 additional mobile connections, as reported by Kemp (2022 and 2023). GSMA Intelligence forecasts 12.40 million mobile connections in Libya for 2024, an increase of 291,000, or 2.4%, compared to the prior year (Kemp, 2024). The increasing use of smart devices and mobile phones by Libyan youth may compel higher education institutions to incorporate and integrate emerging technologies. Students' technological proficiency can facilitate their transition to IoT-enabled instructional technologies, enhancing pedagogy and learning outcomes. As the world increasingly digitises, students may acquire job-market skills through the IoT. The widespread adoption of smart devices has the potential to modernise Libya's higher education system, enhancing its efficiency, accessibility, and digital relevance. By prioritising digital infrastructure, e-government projects, and modernised IT systems, Libya can achieve significant educational advancements (Elmansori & Ishak, 2021). Ultimately, these initiatives reflect Libya's commitment to higher education development, ensuring students receive a high-quality, technology-driven learning experience (Al-Abbar, 2021; Ericsson, 2021; Saleh, 2020).

IoT Integration in Libyan Higher Education

Beyond conventional ICT advancements, the integration of new technologies presents a transformative opportunity for improving Libyan higher education. Despite their considerable promise, traditional e-learning platforms, including Massive Open Online Courses (MOOCs), frequently demonstrate limitations in effectiveness, engagement levels, reinforcement mechanisms, design quality, social media integration, and accessibility features. The implementation of e-learning may lead to social isolation, with its limited relevance to specific academic disciplines. Moreover, the lack of sufficient support for students with disabilities (Tamm, 2023; James, 2023; Firat, 2016; Fidalgo *et al.*, 2020). Kamar *et al.* (2016) assert that traditional e-learning systems demonstrate constraints regarding scalability and availability. These systems are incapable of efficiently allocating processing resources and possess limited storage capacity. Furthermore, the seamless transmission of information among users continues to pose a barrier in these systems. Mansor *et al.* (2020) assert that traditional face-to-face training and e-learning platforms in higher education institutions (HEIs) lack the interactive capabilities inherent in digital technology. The existing curriculum at higher education institutions (HEIs) inadequately meets student needs due to insufficient adaptation of educational techniques that align with Education 4.0 concepts. Therefore, to adequately address these concerns, several scholars recommend that e-learning platforms prioritise the delivery of engaging and interactive educational materials. Furthermore, they have to integrate reinforcement mechanisms to enhance information retention and foster a collaborative learning environment. Multimedia resources should be included, and regular feedback and assistance should be provided to promote continuous learning. Personalised learning experiences should be implemented to guarantee accessibility for all learners. Finally, it is essential to

guarantee the availability of inclusive and accessible content to address the varied requirements of learners. Furthermore, it is essential for platforms to incorporate social media integration and offer extensive support across several disciplines to cultivate an extensive educational experience (Advisor, 2023; Pavlou, 2021; Pappas, 2014). Accordingly, all these considerations lead to one conclusion that emphasises the essential requirements for integrating information and communication technologies (ICT), including the IoT, within educational frameworks. The aim is to establish a ubiquitous learning environment that effectively manages every aspect of the learning process to intelligently configure the learning system (Kamar *et al.*, 2016). Elneel *et al.* (2023) claim that the integration of IoT technologies is crucial for the enhancement of e-learning systems. The authors argue that integrating the IoT can promote interconnectivity, improve reliability, and increase the overall user experience in education. The Internet of Things transforms traditional e-learning into a dynamic, interactive experience through the use of smart devices (Elneel *et al.*, 2023). Moreover, the absence of social connection presents a significant obstacle for students employing online learning platforms. This necessitates the integration of Internet of Things (IoT) technologies to enhance student participation in the digital learning environment (Elsaadany & Soliman, 2017). Today, the concept of intelligent e-learning has arisen via the integration of many technologies. The integration of IoT, artificial intelligence (AI), and virtual reality (VR) tools establishes a comprehensive system that enables improved oversight of students by instructors during teaching sessions and evaluations (Zaguia *et al.*, 2021). It is unquestionable that the IoT has a hugely positive impact on the realm of the education process. Therefore, it can be asserted that the integration of the IoT by universities and higher institutions in Libya may provide potential solutions to their existing challenges and mitigate their consequences. The networked devices and intelligent systems of IoT have the potential to transform campus operations, research, and education. The adoption of IoT is crucial for aligning with Libya's overarching IT objectives, as evidenced by the government's collaborations with UNESCO and initiatives for a national ICT resource centre (UNESCO, 2024). By adopting IoT, Libyan institutions could circumvent conventional developmental obstacles, establishing themselves as regional frontrunners in smart education and research.

Case Studies and Practical Examples

The implementation of IoT in higher education has exhibited considerable promise via numerous international initiatives. Although the integration of the Internet of Things (IoT) into higher education in developing countries remains in its early stages, several significant initiatives illustrate its promise and deserve further attention. For instance, in Burkina Faso, a virtual university leveraged IoT technologies to expand access to tertiary education by overcoming physical infrastructure limitations (Pisani, 2024). Similarly, China's Guangdong Compulsory Education Project employed IoT tools to distribute digital teaching materials, enabling real-time updates and improved access for both teachers and students in remote and underserved regions (Pisani, 2024). At Indonesia's Politeknik Negeri Pontianak University, a smart IoT system was deployed to automate lighting and air conditioning in laboratories (e.g., Informatics Engineering Laboratory). The system uses scheduling and occupancy detection to optimise power consumption, enabling both automated and human

control to enhance energy efficiency, reduce operating costs, and minimise environmental impacts (Wibowo *et al.*, 2024). Meanwhile, Brazil's GENIOT project at Unicamp targeted IoT-based energy management, particularly air-conditioning systems which account for 40% of campus electricity consumption. This system integrates hardware and software to monitor energy data and manage the energy consumption process. It also considers occupants' comfort demands, lighting levels, and energy waste control, combined with investments in energy efficiency to optimise air-conditioning use (Yasuoka *et al.*, 2023). These case studies from several developing countries highlight IoT's transformative role in enhancing accessibility, resource efficiency, and sustainability in higher education institutions worldwide. The integration of the IoT in higher education exhibits global promise; yet, implementation challenges remain, particularly in developing nations. A case study at Al-Zaytoonah University of Jordan revealed significant impediments to the effective deployment of IoT on campus, including technical challenges, inadequate infrastructure, insufficient training, security vulnerabilities, and doubts concerning the reliability of IoT-based assessments (Derbas *et al.*, 2025). These findings highlight the essential requirements for institutional readiness, which include robust infrastructure, extensive training programmes, and strong cybersecurity protocols as prerequisites for effective IoT integration in higher education environments. The Jordanian experience offers a significant lesson for other developing nations contemplating analogous technology transformations, highlighting that technological capacity alone cannot overcome systemic unpreparedness.

Recommendations for Effective Integration

To ensure successful implementation of IoT in higher education, institutions should adopt a strategic approach that addresses both technical and institutional challenges. First, policymakers should establish a comprehensive national IoT strategy that delineates explicit regulatory frameworks and allocates specific funding for educational technologies. This plan should involve incentives for innovation and collaborations with technology companies. Second, higher education institutions should make investments in scalable and robust ICT infrastructure that facilitates IoT integration. This includes upgrading network capabilities, ensuring access to high-speed internet, and providing adequate security measures to protect sensitive data. Third, institutions have to prioritise ongoing professional development for their faculty and students, providing them with essential skills and knowledge to deploy the IoT efficiently. Faculty members have to prioritise the integration of IoT competencies and instruments in their curricula. This may encompass project-based learning and practical activities that improve students' preparedness for the digital economy. Fourth, establish comprehensive data governance frameworks within higher education institutions to ensure compliance with legal standards, protect data security, and uphold user privacy. This includes defining data ownership, enforcing access controls, and adhering to international best practices in data management and protection. Fifth, engage actively with government agencies to secure policy alignment and regulatory support for Internet of Things (IoT) initiatives. This partnership is essential to ensure IoT projects are guided by national priorities, benefit from legal clarity, and receive institutional backing at every stage of development and implementation. Lastly, the study acknowledges possible barriers to IoT adoption, including

financial limitations and resistance to change. The study recommends investigating alternate funding sources, including grants, private sector collaborations, and overseas aid, which may reduce budgetary constraints. The implementation of IoT projects gradually might facilitate cost management. To mitigate resistance to change, this study suggests developing a robust communication strategy that stresses the advantages of IoT and presents success stories to foster acceptance. Engaging teachers and staff in decision-making processes and providing training sessions can facilitate the transition and enhance commitment. By following these recommendations, higher education institutions can harness the full potential of IoT to drive innovation and improve learning outcomes for students.

Conclusion

In conclusion, while Libyan higher education faces challenges and opportunities for improvement, the IoT implementation presents both challenges and opportunities for Libyan higher education. While the integration of IoT technologies can enhance teaching and learning experiences, improve administrative processes, and facilitate research activities, there are also barriers that need to be addressed. These challenges include issues related to data security, privacy concerns, lack of technical expertise, limited financial resources, and inadequate infrastructure. To maximise the benefits of IoT in higher education institutions in Libya, a comprehensive strategy must be developed to address these challenges. This strategy should involve investing in cybersecurity measures, providing training for staff and students, securing funding for IoT projects, and enhancing the technological infrastructure. By overcoming these obstacles, Libyan universities can harness the full potential of IoT to revolutionise education and research practices in the country. Future research should focus on investigating the effectiveness of such strategies in the Libyan higher education context

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