(REVIEW ARTICLE)

# Transforming E-learning systems with AI and IoT Powered by 6G Technologies

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## Abstract

This study explores the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) within sixth-generation (6G) networks to enhance digital education. A systematic review was conducted on 15 peer-reviewed articles published between 2018 and 2024. The review evaluates how AI enables adaptive learning and real-time analytics while IoT facilitates smart classroom environments and learner monitoring. Findings indicate that combining these technologies over 6G networks improves latency, personalization, and scalability in e-learning. Despite these benefits, challenges such as infrastructure cost, device interoperability, and data privacy persist. The paper concludes by recommending technical strategies and future research directions to optimize AI and IoT integration in smart education systems.

**Keywords :** Network 6G; Artificial Intelligence; Internet of Things; E-learning; Smart Education

## 1. Introduction

E-learning has become essential in modern education due to its ability to provide remote and flexible access to knowledge [12]. However, traditional platforms struggle to meet the demands of real-time feedback, learner engagement, and system scalability. The COVID-19 pandemic exposed the limitations of existing infrastructure in supporting inclusive digital learning [3].

Fifth-generation (5G) networks addressed some of these issues by improving bandwidth and reducing latency [6], yet they fall short in supporting immersive technologies and large-scale device coordination. Sixth-generation (6G) networks aim to overcome these shortcomings with ultra-reliable low-latency communications (URLLC), massive machine-type communications (mMTC), and enhanced mobile broadband (eMBB) [1].

Artificial Intelligence enhances e-learning by enabling adaptive systems, predictive analytics, and automated assessments [4]. IoT devices, such as sensors and RFID tags, enable physical-digital interaction in classrooms, improving monitoring and personalization [2]. When powered by 6G networks, these technologies can work together to provide real-time, immersive learning experiences. However, integrating these systems raises concerns around interoperability, cost, and ethical use of data [5].

This paper investigates the combined use of AI and IoT in e-learning over 6G networks. The following structure is used: Section 2 reviews related work. Section 3 outlines the methodology. Section 4 presents findings. Section 5 discusses challenges and implications. Section 6 concludes the paper.

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## 2. Related Work

Several studies have explored how AI and IoT can enhance educational systems [4][14]. AI applications in education include intelligent tutoring systems, predictive modeling for dropout risk, and dynamic content recommendations. These systems improve personalization and learning outcomes by adapting to individual needs.

IoT implementations, such as smart sensors, enable real-time monitoring of learners' interactions and physical environments [3][10]. These technologies support adaptive interventions and improve classroom efficiency. Despite this, current applications are often isolated, lacking integration across architectures [7].

Most existing solutions rely on 4G or 5G networks, which do not support the full capabilities required by immersive and intelligent education systems [11]. Moreover, challenges related to data privacy, interoperability, and standardization remain [13].

### 2.1. 6G Networks and Smart Education Architectures

6G networks are expected to provide ultra-low latency, pervasive intelligence, and context-awareness for advanced educational systems [1][6]. Features such as terahertz communication, reconfigurable intelligent surfaces (RIS), and AI-native networking create opportunities for real-time learning [14].

Studies show that 6G can support extended reality (XR) and haptic feedback in smart classrooms [11]. AI-as-a-Service over 6G enables fast decision-making and personalized resource allocation [4][8]. Integration with energy-efficient IoT devices ensures scalability [10].

However, challenges include spectrum allocation, device heterogeneity, and lack of interoperability standards [5]. Future research must co-design educational goals and network protocols to align pedagogical outcomes with technical performance.

## 3. Methodology

This review analyzed 15 peer-reviewed articles from IEEE, Springer, Elsevier, and MDPI between 2018 and 2024. The selection criteria included:

- Relevance to AI or IoT in education
- Focus on 5G or 6G infrastructure
- Technical and pedagogical contributions
- Articles were coded thematically into five categories:
- Pedagogical innovation
- System architecture
- Personalization and analytics
- Data privacy and security
- Network performance
- Studies not addressing education directly or lacking technical depth were excluded.

## 4. Results and Discussion

This review identified significant contributions of Artificial Intelligence (AI), the Internet of Things (IoT), and 6G networks to the evolution of e-learning systems. The analysis of selected studies revealed that AI enhances personalized learning, automates assessment, and enables real-time feedback. IoT supports intelligent monitoring through connected devices, sensors, and data collection tools. 6G provides the low-latency, high-bandwidth infrastructure needed to operate these technologies in real-time environments.

To highlight the comparative strengths of each component, Table 1 summarizes their roles within smart education systems.

**Table 1** Comparative roles of AI, IoT, and 6G in Smart Education Systems

| Technology | Role in E-Learning | Key Functions | Examples |
|---|---|---|---|
| AI | Personalization and analytics | Intelligent tutoring, behavior prediction, automated feedback | Adaptive learning platforms, student performance analysis |
| IoT | Real-time monitoring | Sensor data acquisition, environment tracking, biometric capture | Smart classrooms, wearable learning devices |
| 6G | Infrastructure support | Ultra-low latency, real-time transmission, AI-native connectivity | Extended Reality (XR), cloud-based synchronous learning |

The convergence of these technologies leads to more immersive and intelligent educational experiences. AI can analyze learner behaviors to adapt course content dynamically. IoT devices collect real-time data, such as motion, attention levels, and biometric signals. With 6G, this data can be transmitted with negligible latency, enabling instant feedback and interaction.

Several studies emphasized that such systems improve learner engagement and reduce dropout rates [12][15]. However, challenges remain. Integration requires significant infrastructure investment, especially for developing regions. There are also concerns about data privacy, interoperability of devices, and energy consumption of continuous real-time data processing [5][10].

Moreover, while theoretical models exist, few real-world implementations demonstrate the full integration of AI, IoT, and 6G. Existing pilot projects are often limited in scale and lack longitudinal data. This suggests the need for collaborative frameworks between researchers, educational institutions, and telecom providers.

Finally, ethical concerns about data ownership and surveillance must be addressed through clear regulations and transparent technology design. Initiatives involving federated learning, blockchain-based access control, and explainable AI are emerging to mitigate these risks but remain in early development stages.

## 5. Conclusion

This study analyzed the integration of Artificial Intelligence (AI), Internet of Things (IoT), and sixth-generation (6G) networks in e-learning environments. The findings reveal that AI enables personalized learning through adaptive systems and predictive analytics. IoT contributes real-time monitoring and interactive experiences via connected devices. 6G provides the infrastructure for ultra-low latency and intelligent data transmission, essential for immersive and responsive digital learning.

The combined use of these technologies has the potential to significantly enhance educational outcomes by offering scalable, accessible, and adaptive platforms. However, successful implementation depends on addressing key challenges, including infrastructure cost, interoperability, data security, and ethical concerns.

Future work should focus on designing integrated frameworks that align educational objectives with technological capabilities. Collaborative efforts involving researchers, developers, and institutions are necessary to build inclusive and effective smart education ecosystems.

## Compliance with ethical standards

*Disclosure of conflict of interest*

The authors declare that they have no competing interests.

*Statement of ethical approval*

The present research work does not contain any studies performed on animals or human subjects by any of the authors.

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