

Research Article:

## AI and IoT in Education: Enhancing Classroom Interactivity and Student Engagement

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### ABSTRACT

This study examines how the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) can enhance classroom interactivity and student engagement in technology-supported educational environments. Using a systematic literature review guided by PRISMA procedures, the study analyses 67 peer-reviewed publications drawn from major academic databases including Scopus, Web of Science, IEEE Xplore, and Google Scholar. The review synthesises existing research on the pedagogical applications of AI-driven adaptive learning systems and IoT-enabled smart classroom technologies. The findings indicate that AI technologies, particularly intelligent tutoring systems and adaptive learning platforms, enable personalised learning pathways by analysing student performance data and providing real-time feedback. At the same time, IoT-enabled devices such as smart boards, wearable sensors, and connected classroom systems support interactive and data-driven learning environments. When integrated effectively, these technologies contribute to improved classroom interaction, increased student motivation, and more responsive instructional practices. However, the review also identifies significant challenges associated with AI-IoT integration, including digital inequality, infrastructural limitations, data privacy concerns, and algorithmic bias. Addressing these issues requires coordinated efforts among educators, policymakers, and technology developers to ensure equitable and ethical implementation. By synthesising current research and identifying emerging trends, this study contributes to the growing body of scholarship on intelligent educational technologies and provides insights for designing more inclusive and interactive learning environments.

**Keywords:** Artificial Intelligence, Internet of Things, smart classrooms, student engagement, personalised learning

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## INTRODUCTION

### Contextual Background

Digital technologies are increasingly reshaping contemporary educational environments. The integration of digital tools, online collaboration platforms, and artificial intelligence-driven learning systems has expanded opportunities for flexible and personalised learning experiences. These technologies enable students and educators to move beyond traditional classroom boundaries by supporting self-paced learning, virtual interaction, and adaptive instructional practices (Mendoza et al., 2024; Yasin et al., 2024). Artificial intelligence technologies have also been widely discussed as transformative tools for adaptive instruction, automated feedback, and personalised educational support across different learning contexts (Holmes et al., 2023).

The rapid expansion of digital learning tools became evident during the COVID-19 pandemic, when educational institutions worldwide were required to transition to technology-mediated teaching and learning. During this period, online platforms, digital communication tools, and intelligent learning systems played a critical role in maintaining educational continuity and enabling students to access learning resources remotely (Bilous et al., 2022). These developments demonstrated the growing importance of technology-supported education and highlighted the potential of digital systems to support more flexible learning environments. Recent research further suggests that emerging digital systems are redefining learning environments by extending educational experiences beyond conventional classroom boundaries (Hwang & Chien, 2022). Recent international policy discussions also highlight both the transformative potential and ethical challenges of artificial intelligence in education, emphasising the need for responsible governance and equitable access to intelligent learning technologies (Miao & Holmes, 2023).

Despite these advancements, several challenges remain in the integration of technology into educational systems. Access to digital infrastructure remains uneven across regions, particularly in rural or economically disadvantaged communities where students may lack reliable internet connectivity or appropriate digital devices. In addition, educators often require substantial training and institutional support to effectively integrate emerging technologies into pedagogical practices (Yasin et al., 2024; Bilous et al., 2022). Consequently, while digital technologies offer significant potential for enhancing educational experiences, their successful implementation depends on addressing issues of accessibility, infrastructure development, and teacher preparedness (Mendoza et al., 2024; Ilyas et al., 2023).

### Research Problem

Student engagement remains a persistent challenge in many educational contexts. Traditional instructional approaches often rely heavily on lecture-based teaching methods and standardised learning activities, which may not fully address the diverse learning needs and preferences of students. As a result, learners may experience reduced motivation,

limited participation, and insufficient opportunities for collaborative or experiential learning (Badshah et al., 2023; Vijayalakshmi et al., 2024).

Emerging technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) offer promising opportunities to address these limitations by enabling more adaptive and interactive learning environments. AI-driven systems can analyse student performance data to generate personalised learning pathways (Zawacki-Richter et al., 2019), while IoT-enabled devices can connect classroom technologies to create responsive and data-informed learning spaces. Smart classroom technologies, including AI-assisted learning platforms and connected devices, can provide educators with real-time insights into student engagement and academic progress (Tejas et al., 2023; Vashishth et al., 2024).

In addition, IoT-based tools such as wearable devices and smart boards can facilitate more interactive classroom experiences by supporting real-time communication and collaborative learning activities (Meylani, 2024; Piratova et al., 2025). More broadly, IoT technologies provide the infrastructural foundation for smart learning environments by connecting devices, platforms, and real-time classroom data systems (Atzori et al., 2010). AI-driven algorithms also allow learning content to be customised according to individual student performance and learning preferences, thereby supporting more inclusive and differentiated learning environments (Vashishth et al., 2024).

However, integrating AI and IoT technologies also introduces significant challenges related to data privacy, technical infrastructure, teacher preparedness, and equitable access. Educational institutions must address issues such as data security, ethical use of learning analytics, and the need for professional training in order to ensure the responsible implementation of intelligent learning technologies (Mohanty et al., 2023). Although existing research highlights the potential of AI and IoT in education, there remains a need for systematic analysis of how these technologies influence classroom engagement, learning outcomes, and pedagogical practices across diverse educational contexts (Saadé et al., 2023).

Moreover, though a growing body of research explores the application of AI and IoT technologies in education, much of the literature remains fragmented across technological and pedagogical perspectives. Some studies emphasise the technical capabilities of intelligent systems, while others examine isolated classroom implementations without connecting these developments to broader theoretical frameworks. As a result, limited attention has been given to understanding how AI-IoT integration reshapes teaching practices, student engagement, and inclusive learning environments across different educational contexts. Addressing this gap requires systematic synthesis that integrates technological innovation with pedagogical theory and identifies patterns, opportunities, and challenges across international research.

From a global perspective, the integration of AI and IoT technologies in education is increasingly viewed as a key component of digital transformation strategies across higher education and school systems. Countries with advanced digital infrastructures are rapidly

experimenting with intelligent classrooms and adaptive learning systems, while developing regions continue to face structural barriers such as limited connectivity, insufficient training, and unequal access to technological resources. Understanding how these technologies function across diverse educational contexts is therefore essential for developing inclusive and sustainable models of technology-enhanced learning. International organisations have also emphasised the importance of integrating artificial intelligence into education systems in order to prepare learners for digitally mediated economies and future workforce demands (OECD, 2021).

From a global perspective, the integration of AI and IoT in education raises critical questions regarding how technologically advanced and resource-constrained educational systems can equitably adopt intelligent learning environments while maintaining pedagogical integrity and data governance.

### **Study Purpose and Scope**

This study investigates how the integration of AI and the IoT can transform conventional classrooms into interactive, adaptive, and student-centered learning environments. By synthesising existing research on AI-driven learning systems and IoT-enabled smart classroom technologies, the study explores how these innovations contribute to enhanced classroom interaction, personalised learning experiences, and improved student engagement.

The review examines how AI technologies enable adaptive learning through intelligent tutoring systems, automated feedback, and real-time analytics, while IoT devices support interactive classroom environments by connecting digital tools, sensors, and communication platforms. The study also considers broader implications of AI-IoT integration, including the potential to support collaborative learning, facilitate remote education, and strengthen resilience in educational systems during disruptions such as pandemics or natural disasters (Kamruzzaman et al., 2023).

Through systematic analysis of existing literature, the study aims to identify emerging trends, key challenges, and future directions for integrating intelligent technologies into education. By doing so, it contributes to ongoing discussions regarding the role of technology in shaping more inclusive, flexible, and effective learning environments for the 21st century.

### **Significance of the Study**

This research is particularly important for educators, policymakers, and technology developers to understand how AI and IoT can revolutionise conventional classrooms into dynamic student-centred learning environments. It provides educators with evidence-based strategies to improve engagement, individualise learning and manage classrooms more effectively by using real-time analytics and adaptive technology. It helps policymakers understand how to close the digital divide and make it an equitable process and create

ethical regulations that will protect fairness and privacy. These findings can assist technology developers in developing solutions that are pedagogically relevant, inclusive, and scalable depending on the various educational settings. Integrating literature on AI and IoT, the study draws up numerous opportunities as well as challenges that include increased collaboration, flexibility, bias, cost, and infrastructure issues. Finally, it offers a path of action to work jointly on creating a better, more equitable learning system powered by AI and IoT to adapt to various learners and prepare educational experiences to serve the 21st century.

## **Research Objectives**

1. To assess the effectiveness of AI-IoT integration in education.
2. To investigate how the use of AI and IoT allows a smart classroom to include various learning styles and needs.
3. To explore how AI-IoT technologies help design resilient, adaptive, and collaborative teaching learning ambience.
4. To evaluate how AI supports diverse learning styles through constructivist principles and TPACK.

## **LITERATURE REVIEW**

### **Technological Integration in Education**

The technological expansion in the field of education is defining, redefining, and modifying teaching and learning landscapes. It has been found by the existing literature that technology integration in pedagogies makes education more creative, active, and critical (Hamzah et al., 2024) and AI and IoT can bear the limelight in this regard. The tailored and cutting-edge learning experience provided by AI-based adaptive platforms and intelligent tutoring systems makes curriculum and learning more individualistic, addressing every individual's learning needs (Marouf et al., 2025; Vashishth et al., 2024). Teaching aided by wearables and smart boards (IoT) enables more communicative lessons that elicit active interactions (Meylani, 2024; Piratova et al., 2025). IoT technologies have been widely recognised as the infrastructural basis of smart environments because they connect physical devices, digital platforms, and real-time monitoring systems in ways that support responsive and data-informed learning spaces (Atzori et al., 2010). AI algorithms allow students to customise learning content based on their progress, aligning with diverse learning styles (Vashishth et al., 2024).

In the Technological Pedagogical Content Knowledge (TPACK) framework proficiency of teachers using the three aspects, the content, pedagogy, and technology, is prioritised (Sofwan et al., 2024). TPACK-trained educators are more competent to use technology and upgrade the engagement and achievement of students. Nevertheless, many factors challenge the benefits of technology integration. The digital divide persists to restrict access among

the students living in poor or unpopulated regions (Mohanty et al., 2023). It is necessary to focus on the problem of data privacy, AI bias, and what is known as a problem of fairness (Yue et al., 2024). Additionally, a considerable number of educators do not receive sufficient training, and this fact indicates the necessity of constant professional growth (Samad & Arifin, 2024). Technology can also facilitate the management of education and community response, which allows more satisfying and productive learning conditions (Kurniawan et al., 2024; Pujilestari, 2024).

### **AI and IoT in Education**

The combination of the AI and the IoT is revolutionising education with the concepts of personalisation, adaptability and responsiveness in real time. Adaptive platforms and intelligent tutoring systems (ITS) use AI to interpret student performance to build personalised learning paths that allow students to move through the material as individuals in their own time at their own pace. Based on this plan, engagement, motivation, and success are enhanced (Onesi-Ozigagun et al., 2024; Ayeni et al., 2024). The improved administration demands, such as grading and tracking, that AI facilitates permit instructors to have interactive instruction and higher-order thinking. Moreover, AI-powered chatbots and virtual assistants offer real-time human like responses and thus create the interaction and student-centred atmosphere (Kamruzzaman et al., 2023). FAI-driven educational systems are increasingly recognised as tools capable of supporting adaptive instruction, personalised feedback, and data-informed pedagogical decision-making (Holmes et al., 2023).

Simultaneously, IoT integrates the physical and digital learning environments and bridges the gap between the two by using special devices such as wearables, smart cameras, sensors, and smart whiteboards. The tools can collect real-time data about the student engagement, behavioural, and emotional statuses that can be further applied by means of AI to modify supplied contents, strengthen various instructions (Vashishth et al., 2024). IoT also facilitates smooth coordination through its interconnection of equipment to access resources and interactive operations. In addition to pedagogy, it improves campus administration through systems that save and produce energy, security control, and smart space-reuse (Meylani, 2024).

Technological combinations based on AI and IoT, or AIoT, allow real-time adaptive decision-making based on data, which is becoming valuable as an English language educator because it keeps content up-to-date with the changing needs of learners, as well as the pace and delivery methodologies (Tejas et al., 2023). This synergy not only optimises learning to a high level but also prepares students to have the kind of skills required in the future, which will be technologically driven.

Nevertheless, data privacy, bias, and access, among others, are among the challenges which will need to be addressed to make it fair and inclusive (Sandrilla, 2024; Leong et al., 2025). AI and IoT can be transformative in ensuring more responsive, appealing and personalised

learning to education needs and with adequate safeguards to educational alteration (Priya et al., 2024).

### **Critical Synthesis of Existing Literature**

The reviewed literature consistently highlights the potential of AI and IoT technologies to transform educational environments by enabling adaptive learning, improving classroom interactivity, and facilitating data-driven instructional decisions. Many studies emphasise the effectiveness of AI-powered learning systems in providing personalised learning experiences that respond to individual student performance and learning pace. Similarly, IoT-enabled classroom environments allow educators to collect real-time data about student engagement and environmental conditions, thereby supporting more responsive teaching practices.

However, the literature also reveals several conceptual tensions and implementation challenges. While AI-driven systems can enhance personalisation and efficiency, some scholars argue that excessive reliance on algorithmic recommendations may reduce opportunities for exploratory learning and teacher-guided interaction. Additionally, the effectiveness of IoT-enabled learning environments depends heavily on institutional infrastructure, teacher preparedness, and ethical governance of student data.

Another key finding emerging from the literature is the uneven distribution of technological benefits across educational systems. Research conducted in technologically advanced regions often reports the successful implementation of smart learning environments supported by robust digital infrastructure. In contrast, studies from developing contexts frequently highlight barriers such as limited connectivity, insufficient teacher training, and concerns regarding accessibility and digital equity. These differences indicate that technological innovation alone cannot guarantee meaningful educational transformation; instead, effective integration requires supportive institutional policies, teacher training, and inclusive technological strategies.

### **Key Challenges and Research Gaps**

Although the potential of AI and IoT in the field of education is enormous, significant challenges need to be addressed to make the integration equal and useful.

#### ***Equity and access***

The availability of devices, good internet service, and assistance is limited due to socioeconomic barriers that specifically haunt the underserved and rural areas, which continues to reinforce the existing inequity system in education (van Gestel, 2025; Huang et al., 2024). Scarcity of cultural and linguistic information in training usually makes irrelevant or biased the content, which makes it non inclusive (Bhatia et al., 2024; Diene,

2024). Moreover, there is a lack of gender and minority groups that potentially spawns stereotypes and curtails opportunities (Chinta et al., 2024; Fazil et al., 2024).

### ***Algorithmic bias and transparency***

The biased representations of unbalanced datasets can be reproduced by AI systems, which result in discriminative grading, assessments, or recommendations (Fazil et al., 2024; Chaudhary, 2024; Diene, 2024). The lack of transparency in most algorithms, through their black-box models, prevents the identification and correction of inequalities (Diene, 2024).

### ***Accessibility and the digital divide***

The inability to access the required infrastructure including the lack of fixed connection and adequate digital literacy grows inequalities, restricting the opportunities to contribute to the AI development process (van Gestel, 2025; Huang et al., 2024).

### ***Limitations of mitigation strategies***

Although mechanisms of detecting biases and diversifying the datasets are in place, they tend to focus primarily on promoting fairness, not accuracy and cannot be supported by solid ethical guidelines (Dimitrakopoulou et al., 2024; Zhou et al., 2022; Chaudhary, 2024).

### ***Pathways forward***

To achieve accountability and trust, injury-free integration of inclusive AI should be realised, and this will require bias audits, diverse teams in AI development, participatory design, and explainable AI frameworks in order to achieve this goal (Fazil et al., 2024; Bhatia et al., 2024). The need of multi-stakeholder cooperation should be aimed at closing accessibility gaps and contributing to fairer and sustainable adoption of AI in the sphere of education (Morandín-Ahuerma, 2024; Zhang, 2024).

Despite the growing number of studies examining AI and IoT in education, few systematic reviews critically integrate technological innovation with pedagogical theory to explain how these systems reshape teaching practices, learner engagement, and educational equity across diverse global contexts.

## **THEORETICAL FRAMEWORK**

### **Constructivist Learning Theory**

Constructivist Learning Theory linked to both Jean Piaget (1970) and Lev Vygotsky (1978) indicate that the learner does not simply intake knowledge but actually creates the knowledge through interaction, exploration and reflection. Piaget focused on the

development of cognition in the context of experiential learning, which implies the creative adjustment and improvement of mental patterns. Vygotsky (1978) carried this further by emphasising the sociocultural aspect of learning and coined the important concepts of the Zone of Proximal Development and scaffolding and how learners develop through guided help.

AI and IoT are connected with these principles very well. Adaptive learning platforms driven by AI can support the unique scaffolding that is associated with the approach of Vygotsky (1978) by customising the learning content to the pace and expertise of a particular learner. Equally, IoT-enabled smart classrooms, in which interactive whiteboards, wearable sensors, and connected devices are used, help students to work cooperatively within problem-driven learning that aligns with the idea of active discovery by Piaget (1970). Such technologies introduce possibilities of real, practical learning that provides both individual and knowledge building through social mediation. However, the increasing reliance on algorithm-driven personalisation raises theoretical questions regarding the balance between automated instructional guidance and learner autonomy, suggesting potential tensions between constructivist principles and AI-mediated learning environments.

### **Technological Pedagogical Content Knowledge (TPACK)**

More recently, a model known as Technological Pedagogical Content Knowledge (TPACK) has been developed by Punya Mishra and Matthew J. Koehler (2006) based on the concept of Pedagogical Content Knowledge (PCK) described by Shulman (1986). According to TPACK, effective technology-based teaching entails combining the Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK).

In the context of learning practices in AI-IoT-informed learning spaces, TPACK can be seen as reinforcing strategic considerations toward guiding how educators can best ensure that technology is used to legitimate teaching and learning within the needs of the pedagogical purposes, rather than a shadowing pedagogical purposes. As an example, learning gaps can be detected using AI analytics which can provide information to the teacher so that they can either visit that aspect of learning or just adjust instruction (Mishra & Koehler, 2006). The devices of IoT can then offer real-time interactive simulation or data collection chances which add conceptual understanding. Educators with a TPACK knowledge skills can therefore select, adapt, and deploy AI to IoT tools in pedagogically sound and curriculum goal-consistent manners to achieve meaningful learning outcomes. Nevertheless, the emergence of AI-driven instructional systems also challenges traditional interpretations of the TPACK framework by shifting certain pedagogical decision-making processes from teachers to algorithmic systems, raising questions about teacher agency in technology-enhanced classrooms.

## **Integrating Constructivism and TPACK in AI–IoT Classrooms**

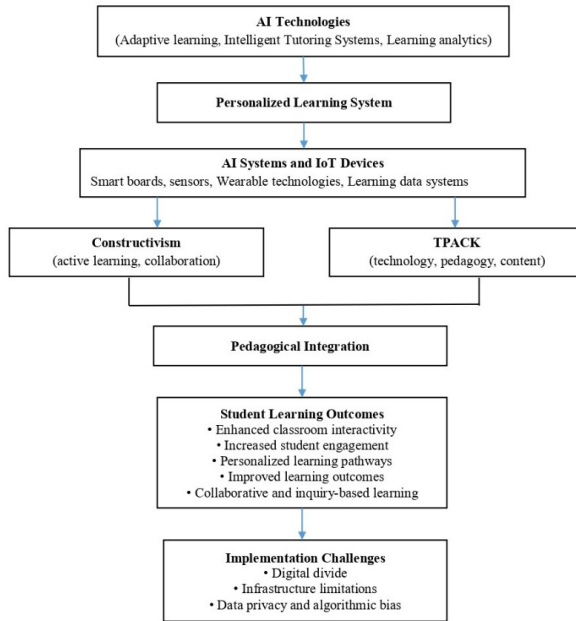
When used simultaneously, Constructivist Learning Theory and TPACK form a complete basis that enables the use of AI and IoT in learning. The constructivism theoretical approach explains the pedagogical approach learners-centred and inquiry-based learning approaches (Piaget, 1970; Vygotsky, 1978), whereas TPACK comes up as the practical model of integrating into the process of teaching and learning, with technological tools making a significant difference in the process (Mishra & Koehler, 2006; Shulman, 1986).

An instance, in a STEM lesson that depends on a project, the constructivist model may challenge the students to research issues on the real world and do it collectively. With the assistance of TPACK, personalised resources and formative feedback may be presented through AI analytics, and IoT facilities may be used to ensure real-time data gathering during experiments. This synergy will result in the purposeful use of technology, active construction of knowledge, and make individual and team learning processes more enhanced.

## **Conceptual Framework of AI–IoT Enabled Smart Learning Environments**

To synthesise the theoretical perspectives discussed above, this study proposes a conceptual framework illustrating how AI and IoT technologies interact with pedagogical theories to shape smart learning environments. The framework integrates AI-driven adaptive learning systems and IoT-enabled classroom technologies with constructivist learning theory and the TPACK framework. Within this model, AI technologies such as intelligent tutoring systems, learning analytics, and adaptive platforms support personalised learning processes, while IoT devices, including sensors, wearable technologies, and smart boards—facilitate real-time interaction within classroom environments. These technologies enable the development of AI–IoT smart classrooms that support interactive, student-centred learning. Pedagogical integration guided by constructivist principles and the TPACK framework ensures that technological tools are meaningfully aligned with instructional strategies and subject content. Ultimately, this integration contributes to improved student learning outcomes, including increased classroom interactivity, personalised learning experiences, and collaborative engagement, while also highlighting important challenges such as digital inequality, infrastructural limitations, and ethical concerns related to data governance.

Figure 1 illustrates how AI technologies and IoT-enabled devices interact with pedagogical frameworks to support the development of intelligent classroom environments. The framework highlights the relationship between technological integration, pedagogical alignment, and student learning outcomes.



**Figure 1.** Conceptual framework of AI–IoT enabled smart learning environments

## METHODOLOGY

This study adopts a systematic literature review (SLR) approach to synthesise existing research on the integration of AI and the IoT in educational environments. The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines in order to ensure transparency, reproducibility, and methodological rigor in the selection and analysis of relevant studies.

Relevant publications were identified through searches conducted in four major academic databases: Scopus, Web of Science, IEEE Xplore, and Google Scholar. These databases were selected to ensure comprehensive coverage of educational and technological research related to AI- and IoT-based learning systems. Scopus and Web of Science were prioritised for their broad coverage of peer-reviewed scholarly publications, IEEE Xplore was included for its strong representation of technological and engineering research, and Google Scholar was used as a supplementary source to capture interdisciplinary studies that may not be indexed in traditional academic databases. The search strategy included combinations of keywords such as Artificial Intelligence, Internet of Things, smart classrooms, adaptive learning, and student engagement.

A total of 150 records were initially identified across the selected databases. After duplicate removal and title–abstract screening, 78 full-text articles were assessed for eligibility. Following the application of the inclusion and exclusion criteria, 67 peer-reviewed studies were selected for the final synthesis.

### Inclusion and Exclusion Criteria

1. **Inclusion criteria:** peer-reviewed journal articles published in English within the last 10 years; studies focusing on AI, IoT, or AI–IoT applications in education; studies addressing classroom interactivity, student engagement, personalisation, or related pedagogical outcomes.
2. **Exclusion criteria:** duplicate records; non-peer-reviewed publications; conference abstracts without sufficient analytical depth; studies not directly related to educational applications of AI or IoT; publications lacking adequate methodological or conceptual relevance to the research objectives.

Figure 2 shows how research documents have been searched, removed duplicate records, screened, assessed, excluded, and finally selected for inclusion.

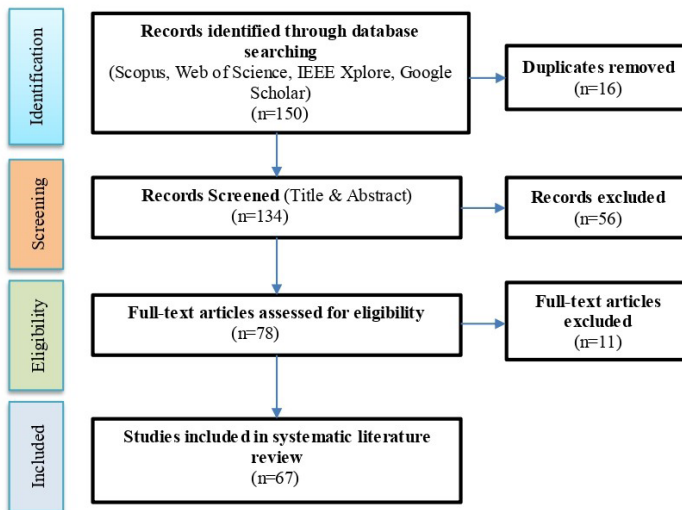


Figure 2. PRISMA flow diagram

## **Manual Coding and Thematic Analysis**

The thematic analysis employed manual coding using an inductive approach in which themes emerged from repeated reading and comparison of the selected studies. To enhance analytical rigor, the coding process involved iterative examination of the studies to identify recurring patterns, conceptual relationships, and methodological approaches. Emerging themes were refined through repeated comparisons across multiple studies, allowing the review to move beyond descriptive summaries and to generate higher-order insights into the pedagogical implications of AI–IoT integration in educational environments. Although the coding was conducted by a single researcher, theme validation was supported through comparison across multiple peer-reviewed studies from diverse contexts.

Although the thematic coding was conducted by a single researcher, analytical reliability was strengthened through repeated comparison of findings across multiple peer-reviewed studies and cross-validation of emerging themes with established frameworks in educational technology research. This approach helped ensure that the identified themes reflected consistent patterns within the literature rather than isolated interpretations.

## **Ethical Considerations**

This study did not involve human or animal subjects and therefore did not require formal ethical approval. However, academic integrity was ensured through accurate citation of all sources and transparent reporting of findings.

## **RESULTS AND DISCUSSION**

The analysis of the selected studies reveals several consistent patterns regarding the integration of AI and the IoT in educational environments. Across the reviewed literature, three major themes emerge: the enhancement of classroom interactivity through IoT-enabled technologies, the role of AI in supporting personalised learning, and the institutional challenges associated with implementing intelligent learning systems. While many studies highlight the pedagogical benefits of these technologies, the findings also indicate that their effectiveness depends on factors such as technological infrastructure, teacher preparedness, and ethical governance of data-driven learning environments.

### **Enhancing Classroom Interactivity with IoT**

The IoT is transforming traditional classrooms into interactive, data-driven learning environments. IoT significantly enhances classroom interactivity by enabling real-time monitoring and feedback. Besides, it can be used to combine smart devices, sensors, and AI-enabled platforms, which will allow checking on student activities and environmental conditions in real-time to make immediate adjustments in the process of instruction (Pogoh et al., 2025; Tejas et al., 2023). To illustrate, it is possible to share learning resources immediately with the help of smart boards, wearable technology, and connected projectors;

motion and presence sensors can provide automatic lighting, temperature control, and activation of multimedia.

Automation is one of the most notable things that IoT brings to the process of classroom management. Systems may facilitate tracking of the attendances, distributed seating allocation in a dynamic fashion as well as managing resources with a view towards curbing the setting of administrative dependency on teachers as well as maximising instructional time (Ojo et al., 2022). IoT systems also have environmental sensors to monitor the quality of air, sound levels, and illumination, aiming at providing a comfortable learning environment that would facilitate the health and concentration of the students (Lopes et al., 2018; Tabuenca et al., 2024).

IoT enables educators to adjust lesson needs in real-time and reacts to signals of disengagement by using real-time data analytics, and adjustment on the fly and timely interventions. It is a data-free method that fits the model of personalised learning, as it provides specially adapted materials depending on the performance of individual students and trends in their attitudes (Sapale & Banerjee, 2023).

### **Case Studies: Practical Applications in Educational Settings**

The power of IoT in educational settings has been demonstrated in numerous case studies. The use of an IoT-based seat allotment system at Federal University of Agriculture Abeokuta, Nigeria, showed an excellent example of efficiency, as it saved time on managing seats and making seat assignments more accurate than manual approaches (Ojo et al., 2022). In European university education, IoT-enabled classrooms have been employed to shape the digital data literacy of learners, exposing learners to the experience of real and live data capture and information processing that gets learners ready to work in data-driven professional settings (Tabuenca et al., 2024).

The use of IoT technologies has extended into allowing ubiquitous learning to be encouraged as well. The presence of context-aware systems enables students to continue with similar learning experiences (blended or distant) and have access to resources both in and outside the classroom (Lopes et al., 2018). Moreover, IoT has also enabled interactive laboratories, in which students can manipulate scientific instruments remotely, access experimental data in real-time, and so forth, increasing engagement and accessibility at the same time (Dhir et al., 2024).

Along with these achievements, the IoT adoption has its pitfalls in terms of the infrastructural demands, security concerns and data privacy (Pogoh et al., 2025; Pradeep, 2023). These problems are crucial to overcome so that trust could remain and unequal access to the learning opportunities made possible by IoT could be avoided.

To a great extent, such integration of the IoT in smart classrooms can result in an active, effective, and student-centered learning process. IoT offers real-time interaction, facilitates group learning, and offers deliverable information to help meet an important enabler of the next-generation pedagogical stature.

## **Personalised Learning Through AI**

### *AI's role in adaptive learning platforms*

Adaptive learning platforms have been greatly transformed by AI-powered systems as they allow the customisation of lessons to accommodate the specific needs of individual students. Such systems are based on machine learning, natural language processing, and more in-depth data analytics that would allow adapting educational content, pace, and assessment to the individual style, skills, and preferences of each learner (Kaswan et al., 2024; Katiyar et al., 2024). Through the constantly updated performance data of students, the AI can guarantee that they get individual support where necessary and more engaging and difficult content where coveted, thus maximising involvement and understanding.

One of the most significant applications of this strategy can be impressed in the application of intelligent tutoring systems (ITS), where we have real-time feedback, learning scaffolding, and personalised suggestions specifically based on students' levels of understanding. They have been especially useful in more technically oriented courses, as well as those involving science, technology, engineering, and mathematics (STEM), where fast, accurate feedback is especially helpful in increasing knowledge (Sun, 2024). The research has shown that adaptive learning systems based on AI enhance the educational process, resulting in higher post-assessment rates and course completion rates than those of the traditional approaches of teaching (Sari et al., 2024; Yamijala et al., 2025).

### *Benefits beyond personalisation*

Improved education is not the only possible AI benefit in education. By automating different administrative duties, including grading, attendance keeping, and reporting on the progress, AI frees educators to spend a lot more of their time on interactive tutorials and personalised teacher-student interactions (Arya & Verma, 2024). The change enables educators to concentrate on promoting thinking strategies, innovation, and group problem resolutions instead of being overworked with trivial, time-consuming assignments.

## **Ethical and Implementation Challenges**

Nevertheless, there are severe obstacles to deploying AI in education despite all the potential benefits. There are ethical issues that need to be taken into consideration like data privacy, algorithmic prejudice, and the digital divide that keeps increasing and has to be bridged (Arya & Verma, 2024; Mimoudi, 2024). The biased datasets reflect in the training of AI systems and, consequently, can simply support the current impact of inequality, producing unfair academic consequences (Mimoudi, 2024). Additionally, excessive dependence on AI could be detrimental to the personalisation of the learning process, given that human teachers introduce unique value to the emergence of emotional intelligence, socialisation, and empathy (Mimoudi, 2024).

In order to implement AI usage efficiently, the efficient infrastructure, access to high-quality and representative datasets, and training of teachers to identify pedagogical value of all those additions are necessary (Kaswan et al., 2024; Sari et al., 2024). Looking into these factors will help determine that AI cannot weaken human front instruction.

AI-powered adaptive learning platforms have the potential to transform education, provided they are put into use in a thoughtful manner that would allow flexibility of learning and individualised experiences that can greatly enhance efficiencies and equity in learning. The trick will be in combining technology efficiency with human- and ethics-driven protection and pedagogy that will mean that AI will not be a tool of exclusion, but of empowerment (Ejjami, 2024; Katiyar et al., 2024).

## **Challenges in Integration**

### ***Equity and access***

Equity and access are one of the most recurrent problems of introducing AI and the IoT in education. The access to technological infrastructure, especially in the underserved areas or in the rural settings has significant gaps, and the unpleasant experience of unreliability in internet connection, obsolescence of hardware and of software and low digital literacy rates prevents the successful implementation of these technologies (Kotsis, 2024). These differences threaten to expand the digital divide, which further contribute to underlying differences in education. To fill such gaps, it is necessary to incentivise infrastructure investment, develop specific policies to address the accessibility of digital technologies, and introduce an equal distribution of resources so that all students, no matter their location and socioeconomic background, can benefit from learning opportunities made possible by AI and the IoT (Eden et al., 2024).

### ***Implementation costs and training***

The next important challenge is in the financial and logistical issues of the adoption of AI and IoT in education. The expenditures related to buying, setting up, and maintaining AI- and IoT-enabled systems may be high, especially for the budgets of the institutions that are located in developing regions (Farooqi et al., 2024). Besides infrastructure, teacher preparedness is needed in these technologies to be successful. It demands time-involving training to educators in acquiring the necessary skills to harness the AI and IoT tools in their pedagogical process (Kotsis, 2024). Nonetheless, bringing such training to large scale incurs more costs, time, and planning, which become disincentives to a large-scale adaptation. The possible advantages of AI and IoT can go to waste unless proper professional development takes place.

### ***Bias and fairness issues***

Prejudice and impartiality are quite important ethical issues in the way of incorporating AI into educational settings. The algorithms learned by AI are no more unbiased than the training data used to produce them; in case the data has historical biases, or does not reflect certain demographic groups, it can create discriminative results (Abimbola et al., 2024; Ojha et al., 2024). This kind of biases may create inequities on students contributing to current social and educational disparities (Yadav, 2024). Additionally, such biases can be difficult to detect and overcome through AI models of decision-making procedures that require transparency. The solutions to these problems will include the extension of transparent and accountable artificial intelligence systems and establishing straightforward principles of their application in education. The governments, education institutions, and technology providers need to work together to develop frameworks that would protect against unfairness but have the greatest pedagogical impact AI (Morandín-Ahuerma, 2024; Zhang, 2024).

In conclusion, to battle such challenges, there is the necessity to strike a balance between technological advancement and equity-based policies, moral oversight, and complex training programmes. In this manner, the stakeholders are ready to make sure that AI and IoT are applied to education in an inclusive, sustainable, and goal-oriented fashion focused on the enhancement of learning by all.

A cross-study comparison of the reviewed literature demonstrates that the integration of AI and IoT technologies contributes to several interconnected educational outcomes. First, IoT technologies enhance classroom interactivity by enabling real-time monitoring of learning environments and facilitating responsive instructional adjustments. Second, AI-driven adaptive systems enable personalised learning by analysing student performance data and generating individualised learning pathways. Third, successful implementation of intelligent classroom systems depends heavily on institutional readiness, including technological infrastructure, teacher training, and policy frameworks governing data security and ethical use of learning analytics. The following tables synthesise the key findings across the reviewed studies in relation to the research objectives.

### **Tabulated Summary of Results**

The thematic analysis of the reviewed studies indicates that AI-IoT integration contributes to multiple dimensions of student engagement and learning effectiveness. These technologies enhance classroom interactivity by enabling real-time monitoring and feedback, support adaptive instruction through data-driven learning analytics, and create flexible learning environments capable of responding to diverse student needs. However, the literature also highlights persistent challenges related to infrastructure limitations, cost of implementation, teacher readiness, and ethical considerations regarding data privacy and algorithmic bias. The following tables summarise the major patterns identified across the reviewed studies.

The patterns identified across the reviewed studies indicate that the educational impact of AI–IoT technologies extends beyond technological enhancement and involves broader pedagogical transformation in classroom interaction, instructional design, and student participation.

Table 1 highlights the role of IoT in enhancing classroom interactivity through tools such as smart boards and wearable technologies. These technologies provide real-time feedback, a factor that has been shown to increase student engagement and participation. While these findings suggest significant potential, challenges regarding cost and infrastructure limitations must be addressed before IoT can be scaled in diverse educational settings. Moreover, while the technology itself is promising, its effective implementation is contingent on both teacher readiness and institutional support, factors that are not sufficiently discussed in the literature.

**Table 1.** Impact of AI–IoT integration on student engagement (Objective 1)

Impact area	Description	Examples/Evidence from literature	Sources
Real-time learning analytics	AI–IoT tracks and responds to student activity, providing instant insights to teachers for adaptive instruction.	Adaptive dashboards updating teacher strategies instantly based on participation and quiz results.	Tejas et al. (2023); Marouf et al. (2025); Vashishth et al. (2024)
Participation increase	Implementation of IoT and AI tools increases active student engagement rates.	Studies report engagement levels rising from 60% to 85% after IoT integration.	Mohanty et al. (2023); Meylani (2024); Vijayalakshmi et al. (2024)
Collaborative learning	IoT devices and AI tools promote teamwork and peer interaction.	IoT-based shared smart boards and AI-coordinated group assignments.	Meylani (2024); Piratova et al. (2025); Hamzah et al. (2024)
Impact area	Description	Examples/Evidence from literature	Sources
Motivation boost	Gamification and AI-driven personalised content increase motivation.	AI gamified platforms adapting challenge levels to learners’ progress.	Priya et al. (2024); Ayeni et al. (2024); Onesi-Ozigagun et al. (2024)

Table 2 summarises studies that emphasise the power of AI to personalise learning and adapt to students’ individual needs. AI-powered systems, such as adaptive learning platforms, have shown to enhance motivation and learning outcomes by providing customised content. However, there is a notable gap in understanding how personalised learning impacts long-term academic achievement and whether the benefits observed are

sustainable across various demographic groups. Future research should explore not only the efficacy of AI-driven systems but also their accessibility, particularly for underprivileged students who may lack access to necessary technology.

**Table 2.** Adaptation of smart classrooms to diverse learning styles (Objective 2)

Adaptation strategy	Technology used	Pedagogical benefit/ example	Sources
Adaptive content delivery	AI-driven ITS customises pace, sequence, and complexity based on learner performance.	ITS providing easier exercises to struggling learners and advanced problems to proficient ones.	Kaswan et al. (2024); Katiyar et al. (2024); Sari et al. (2024)
Multimodal learning	IoT devices enable multimodal input (visual, auditory, kinesthetic).	VR/AR with IoT sensors allows hands-on simulations for STEM topics.	Piratova et al. (2025); Meylani (2024); Marouf et al. (2025)
Accessibility enhancements	AI voice-to-text and IoT-enabled captions support ESL and special needs learners.	Automated subtitles and smart captioning for lecture recordings.	Huang et al. (2024); Wulandari et al. (2024); Diene (2024)
Adaptation strategy	Technology used	Pedagogical benefit/ example.	Sources
Culturally responsive content	AI algorithms provide localised and culturally relevant learning material.	AI generates examples based on students' regional context.	Bhatia et al. (2024); Chinta et al. (2024); Diene (2024)

Table 3 lists the common barriers identified in the studies regarding the implementation of AI and IoT technologies in education. Notably, issues like cost, technical infrastructure, and data privacy concerns are consistently cited as major obstacles. While these findings are well-documented, there is a need for more in-depth discussion on how educational institutions can overcome these challenges. Specifically, strategies for cost-effective implementation and the development of secure, scalable frameworks are crucial to ensuring that AI and IoT can benefit a wider range of educational environments.

**Table 3.** AI-IoT role in flexible, collaborative, and crisis-resilient learning environments (Objective 3)

Role	Description	Case examples	Sources
Remote engagement	AI-IoT-supported online learning keeps students engaged during disruptions.	COVID-19 remote learning using IoT-based attendance and interaction monitoring.	Kamruzzaman et al. (2023); Sandrilla (2024); Mohanty et al. (2023)

(Continued on next page)

**Table 3.** (Continued)

Role	Description	Case examples	Sources
Space flexibility	IoT environmental control optimises learning conditions in real-time.	IoT-regulated lighting, seating layouts, and temperature control.	Ojo et al. (2022); Meylani (2024); Vijayalakshmi et al. (2024)
Role	Description	Case examples	Sources
Crisis resilience	AI dynamically adjusts schedules and resources during emergencies.	AI-powered adaptive timetables for disaster-prone regions.	Vijayalakshmi et al. (2024); Saadé et al. (2023); Pujilestari (2024)
Sustainable learning	Energy-efficient IoT systems reduce costs and environmental impact.	Smart campus with automated lighting and HVAC systems.	Meylani (2024); Kurniawan et al. (2024); Hamzah et al. (2024)

Above all, AI and IoT enhance interactivity, personalise learning, and create adaptive environments. However, challenges such as equity and access remain and must be addressed to fully realise their educational potential.

Table 4 aligns with Objective 4, highlighting how AI and IoT integration supports diverse learning styles through constructivist and TPACK-based pedagogical frameworks. These findings emphasise that effective technology adoption is grounded in sound theoretical models connecting pedagogy, content, and technology.

**Table 4.** AI’s role in supporting diverse learning styles through constructivist and TPACK frameworks (Objective 4)

Theoretical basis	AI–IoT application	Pedagogical outcome	Supporting studies
Constructivism (Piaget, Vygotsky)	AI-powered adaptive feedback and IoT-based collaborative simulations encourage active knowledge construction.	Promotes student autonomy, problem-solving, and peer collaboration.	Piaget (1970); Vygotsky (1978); Tejas et al. (2023)
Theoretical basis	AI–IoT application	Pedagogical outcome	Supporting studies
TPACK framework (Mishra & Koehler, 2006)	Integration of technology, pedagogy, and content using AI analytics and IoT tools.	Enhances teacher decision-making and alignment of content delivery with learning goals.	Mishra & Koehler (2006); Shulman (1986); Yamijala et al. (2025)
Constructivist–TPACK integration	AI analytics identify learning gaps; IoT enables hands-on, contextualised learning experiences.	Facilitates meaningful, inquiry-based, and inclusive learning environments.	Marouf et al. (2025); Hamzah et al. (2024)

These findings also reinforce the relevance of constructivist learning theory and the TPACK framework discussed earlier. AI-driven adaptive learning platforms support scaffolded learning processes consistent with Vygotsky's concept of guided learning, while IoT-enabled classroom environments facilitate collaborative and experiential learning aligned with constructivist principles. At the same time, the TPACK framework provides a practical model for integrating intelligent technologies with pedagogical strategies and subject content, ensuring that technological innovation supports meaningful learning outcomes rather than functioning as an isolated instructional tool.

## **RECOMMENDATIONS**

### **Prioritise Teacher Training on AI and IoT Technologies**

Based on the findings from Table 2 (AI and Personalisation of Learning), it is evident that AI technologies can significantly enhance student engagement and achievement when implemented correctly. Teacher training in the use of AI-powered platforms is crucial for successful adoption. We recommend that education ministries implement comprehensive training programs to equip teachers with the necessary skills to effectively integrate AI into their teaching practices. This is aligned with Vygotsky's social constructivism theory, which emphasises the importance of teacher scaffolding in creating interactive, student-centred learning environments.

### **Invest in Affordable IoT Devices and Infrastructure**

Table 3 highlighted that cost and infrastructure are primary barriers to the implementation of IoT in classrooms. To address this, we recommend that educational policymakers collaborate with tech companies to create affordable, scalable solutions for schools, especially in under-resourced areas. This could involve subsidising IoT devices for classrooms and developing low-cost internet solutions. According to Piaget's theory of cognitive development, providing interactive, real-time feedback through IoT tools supports active learning and helps students construct knowledge in an engaging manner.

### **Develop Policies Addressing Data Privacy and Security**

Data privacy and security were identified as significant concerns in Table 3. To mitigate these risks, we recommend the creation of national guidelines for the ethical use of AI and IoT in education, with a particular focus on student data protection. These policies should align with ethical theories of privacy, ensuring that AI-driven systems used in schools comply with privacy standards such as GDPR (General Data Protection Regulation).

### **Implement Pilot Programs for AI and IoT in Diverse Educational Settings**

Evidence from Tables 2 and 3 indicates that while AI and IoT show promise, their successful integration depends on the educational context. We recommend that pilot programs be launched in diverse educational environments to test AI and IoT applications in urban, rural, and underserved schools. This will allow policymakers to evaluate the effectiveness and scalability of these technologies before widespread adoption, ensuring that interventions are tailored to meet the needs of different student populations.

### **Encourage Collaborative Research on AI-IoT Integration**

Building on the findings in Tables 1 and 2, we recommend fostering collaboration between academic researchers and technology developers to bridge the gap between AI and IoT research and real-world applications. This could be achieved by establishing research-practice partnerships that align with theories of technology acceptance (e.g., TAM model) and foster continuous improvements in AI-IoT integration in classrooms.

### **Conceptual Contribution of the Review**

This systematic literature review contributes to the growing body of research on AI-IoT-enabled education in three significant ways. First, it integrates technological research on intelligent learning environments with established pedagogical frameworks such as constructivist learning theory and the TPACK model, thereby bridging the gap between technological innovation and educational theory. Second, the review identifies common patterns across international studies, highlighting how institutional capacity, technological infrastructure, and teacher preparedness influence the success of AI-IoT integration in educational settings. Third, the study emphasises the importance of ethical governance and equitable access in the adoption of intelligent educational technologies. By synthesising findings from diverse educational contexts, this review provides insights that are relevant for educators, policymakers, and technology developers seeking to design inclusive and sustainable digital learning environments.

## **CONCLUSION**

This systematic literature review synthesises recent studies on AI and IoT integration in education, focusing not only on how these technologies enhance student engagement but also on the equity gaps they reveal. While much of the existing literature emphasises the positive impacts of AI and IoT, this review highlights that, without targeted interventions, these technologies may exacerbate disparities, particularly for underprivileged students who lack access to the necessary infrastructure.

The study uniquely contributes to the field by drawing attention to the urgent need for inclusive policy solutions that can bridge the digital divide and ensure equitable access to these transformative educational tools. This is consistent with Vygotsky's constructivist

theory, which emphasises the importance of scaffolding and student-centred learning, suggesting that IoT and AI can be powerful tools for creating personalised, adaptive learning environments. However, as this review shows, their effectiveness will be contingent upon overcoming infrastructure and teacher readiness barriers.

Future research should explore the scalability and sustainability of AI and IoT applications in low-resource settings to ensure these technologies benefit students from all backgrounds. Moreover, policymakers should prioritise affordable solutions and teacher training programs to ensure that AI and IoT are effectively integrated into diverse educational contexts. By integrating insights from educational technology, pedagogy, and intelligent learning systems, this study contributes to a deeper understanding of how AI and IoT technologies reshape classroom practices and learning environments. The review highlights the need to align technological innovation with pedagogical frameworks and institutional policies in order to ensure that intelligent learning systems enhance rather than disrupt educational equity and accessibility. The findings suggest that equitable access to these technologies, combined with systemic policy change, could pave the way for a more inclusive and engaged educational system worldwide.

## **STATEMENT OF ARTIFICIAL INTELLIGENCE (AI) USE**

Some AI tools were used for grammar correction, generating citation, and enhancing the readability of the article. The authors confirm that this article is original, and they take the responsibility of the content.

## **INFORMED CONSENT**

As no human participants were involved in the study, there was no issue of informed consent.

## **CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest.

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