

DOI: 10.5281/zenodo.124261125

# SMART LEARNING ENVIRONMENTS: INTEGRATING IOT AND ICT FOR ADAPTIVE EDUCATION

Ar Anusha Vidyasagar<sup>1\*</sup>, Sailaja Bhaskar Murthy<sup>2</sup>, Dr. Neeti Misra<sup>3</sup>, Dr. Meenal Kulkarni<sup>4</sup>, Dr. Pooja Kapoor<sup>5</sup>

<sup>1</sup>Associate Professor, School of Environment Architecture and Design (SEAD), SRMIST Ramapuram Chennai

<sup>2</sup>Asst. Professor, Department of Computer Applications, DSCASC.

<sup>3</sup>Assistant Professor, School of Business, UPES, Dehradun, India.

<sup>4</sup>Associate Professor, Symbiosis Institute of Health Sciences, Symbiosis International (Deemed University), Pune, Maharashtra, India.

<sup>5</sup>Associate Professor, Department of PGDM, D. Y. Patil PGDM Institute, Akurdi, Pune.

Received: 29/12/2025

Accepted: 25/02/2026

Corresponding Author: Ar Anusha Vidyasagar

## ABSTRACT

*In the context of the fast-growing Information and Communication Technology (ICT) and the Internet of Things (IoT) revolution, the concept of teaching and learning has also changed and new smart schools have been set up, where learning is personalized and adaptive. The purpose of the study is the analysis of the use of the IoT and ICT Technologies in the educational context and the possible influence on improving the effectiveness of the teaching, involving the student and his/her performance. Smart learning environments involve using a network of devices, sensors, cloud-based platforms, learning management systems and real-time data analytics to establish learning environments that are responsive to the individual needs of learners. The use of adaptive learning mechanisms enables the personalised delivery of content, continuous assessment and immediate feedback, enabling pupils to learn at their own pace and according to their preferred learning style. The study is descriptive and analytical with the use of primary and secondary source of information. The primary data was collected through questionnaires that were sent to the educators, students and educational administrators and secondary data was collected from academic journals, policies, books and technology reports. The outcomes indicate that the application of IoT and ICT significantly improves the accessibility, cooperation, resource use and learner directed teaching. Furthermore, smart technologies support decision making based on data, allowing teachers to monitor students' progress and develop individualized interventions that improve students' learning. Although these benefits are excellent, a number of problems remain for effective implementation such as inadequate digital infrastructure, data privacy concerns, cyber security concerns, and continuous teacher training. The researchers' findings suggest that effective integration of IoT and ICT can play an important role in the realization of adaptive education systems, which can cope with the increasingly complex demands of 21st century learning. Educational institutions and policy makers are therefore called into action to invest in technological infrastructure, to ensure that digital literacy is embedded in all aspects of smart learning environments and to ensure strategic planning to enable the smart learning environment to maximise its learning potential and sustainable development.*

---

**KEYWORDS:** Smart Learning Environments, Internet of Things (IoT), Information and Communication Technology (ICT), Adaptive Learning, Personalized Education, Digital Learning, Educational Technology, Learning Analytics, Smart Classrooms, E-Learning, Student Engagement, Artificial Intelligence in Education, Connected Learning Systems, Technology-Enhanced Learning, Sustainable Education.

---

## INTRODUCTION

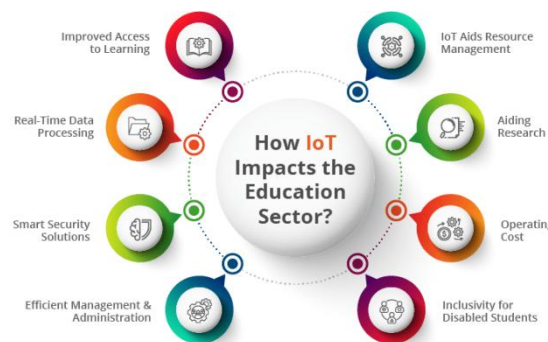
Digital technologies have rapidly developed and changed the face of education, providing opportunities to improve the teaching and learning processes. Information and Communication Technology (ICT) and the Internet of Things (IoT) are some of these technological advancements that have proven to be a powerful enabler in the creation of an intelligent and adaptive learning environment. While knowledge was transmitted and learned mostly one way in a traditional classroom, many emerging learning systems are highly technology driven and focus on personalization, interaction, collaboration, and feedback. The incorporation of IoT and ICT has gained great importance in teaching and learning in the twenty first century as the education institutions try to address the diverse needs of today's students.

Smart learning environments are learning environments where technology plays a key role and where learning is enabled by the use of connected devices, digital platforms, sensors, cloud computing and communication networks, and is therefore dynamic and learner-centered. These settings allow the collection and analysis of data in real-time, which help teachers better track student engagement, progress, and performance. Learning systems can fine-tune instruction, learning sequences and assessment methods based on individual learner needs and thereby enhance learning outcomes using intelligent technologies.

From the perspective of education, the Internet of things helps to connect all physical devices (smart boards, wearable technologies, sensors, tablets, learning management systems) via networked infrastructures. These interconnected devices produce very useful data that can be utilized to comprehend the learning process and optimize its procedures. Meanwhile, ICT provides the digital tools for communicating, sharing content, collaboration, learning virtually and for information management. This combination of IoT and ICT opens up new opportunities for the development of responsive learning environments, personalized learning experiences, remote learning, automated attendance, smart classrooms and data-driven decision making.

The schools, colleges and universities have now started using smart technologies with the rising demand of adaptive education. Adaptive education is an education method which attempts to reflect the differences among individual learning styles, capacities, interests and learning speed. With the information that this data and connected

technologies provide, teachers can identify gaps in learning, provide individualized support and create individualized learning experiences that excite and drive student success. This is particularly helpful in the modern school setting where pupils are from diverse backgrounds and have differing expectations.



Source:

<https://www.extramarks.com/blogs/schools/iot-in-education/>

Moreover, the growing trend toward digital transformation in education has been bolstered by policies that promote the use of technology and innovative teaching and learning methods, as well as by the demand for smart learning infrastructures. The developments are particularly relevant in the blended and online learning models where technology is the medium for the interaction and knowledge dissemination in education.

While there are many positive attributes of a 'smart learning environment', issues regarding infrastructure availability, data privacy, cyber security, digital literacy, and access to technology continue to impact the implementation of these environments. It is therefore paramount to gain insight into the opportunities and constraints of the convergence of IoT and ICT in education, to build sustainable and effective learning ecosystems.

In this context the present research focuses on the role of IoT and ICT in facilitating adaptive learning environments and on the integration of these technologies in order to enhance the effectiveness of learning, learners' engagement and personalized learning. The study aims at shedding light on the future possibilities of smart educational systems as adaptive education.

### **Background of the study**

The world of education has been radically changed in recent years by the rapid growth of digital technologies. The teaching model of "technology supporting teaching" and "individualization, flex

and access", is being used in more and more classrooms, supplementing the traditional classroom teaching model. Out of these technological advancements, Information and Communication Technology (ICT) and Internet of Things (IoT) has emerged as an excellent facilitator in the teaching-learning process. They have developed smart learning environment in adaptive learning, learner-centred and data-driven learning. The contribution of ICT towards access to educational resources, communication and interactive learning experiences has been an important one. With the help of Digital platforms, Virtual classrooms, Learning management systems, Multimedia resources, Online assessment systems, teachers are able to carry out teaching well and students can see teaching anytime and anywhere.

The use of ICT has facilitated the use of innovative pedagogical practices that encourage collaboration, critical thinking and ongoing learning.

Simultaneously, advancement of IoT technologies has opened new ways for the smartness and responsiveness of education environments. Internet of Things (IoT) is a network of devices, sensors, and systems that are able to gather, share, and process real-time data. In educational environments, IoT technologies like smart boards, wearable devices, student attendance monitors, environmental sensors, and integrated learning solutions enable a more seamless learning experience for students, teachers, and learning materials. The technologies provide valuable data that can be used to track learner behaviour, monitor academic growth and fine-tune teaching methods.

Adaptive education has been receiving more and more attention in an attempt to meet the heterogeneous learning needs of children and adolescents. Adaptive learning focuses on tailoring the learning material, rate, and/or teaching approach to the learner's specific characteristics, preferences, and performance level. The use of IoT and ICT technologies offers a solid technological basis for the implementation of adaptive learning, helping to collect data continuously, give feedback on learning progress in real time, deliver personalized content and help in the decisions made in the learning process. These features can help improve learning outcomes, boost engagement, and streamline educational management.

In the era of digital transformation efforts and the increasing need for flexible models, the importance of smart learning environments is becoming even more evident. The promotion of inclusive and technologized learning is increasingly being

supported by investing in digital infrastructure through the efforts of governments, educational institutions and policy makers. Educational reforms, including the introduction of the National Education Policy (NEP) 2020, have been introduced in countries like India to enhance the quality and accessibility of education through the use of digital technologies and innovative teaching approaches. A few countries like India have adopted educational reforms such as the National Education Policy (NEP) 2020, which aims to use digital technologies and innovative teaching methods to enhance the quality and accessibility of education.

Although smart learning environments are becoming more popular, there are still various issues to be addressed in terms of technological infrastructure, digital literacy, privacy of data, costs of implementation, and effective use of IoT and ICT in pedagogy. This is why knowledge of the possible opportunities and constraints is crucial for the educators, administrators and policy makers aiming to create sustainable and effective educational ecosystems.

In this context, the current study aims at finding the ways to use IoT and ICT in designing smart learning environment for adaptive education. This research is designed to investigate these technologies and their contribution to personalized learning, to improve educational efficiency and to transform the learning and teaching environment in a digital world.

### ***Justification***

Digital technologies have transformed learning by providing students with opportunities to experience personalized, interactive and data-driven learning experiences. One of these innovations, specifically the utilization of the Internet of Things (IoT) and Information and Communication Technology (ICT) has been identified as one of the major drivers towards the development of smart learning environments which is adapted for the needs of various learners. It is essential to recognise how digital technologies can be used to improve the teaching, learning and education management process as digital transformation moves into the mainstream of education. Smart learning environments take e-Learning to the next level with the ability to connect devices, implement intelligent systems, harness real-time data analysis and use adaptive learning platforms.

These technologies enable continuous evaluation of the student, can be utilized to provide personalized content, and can offer a way for the

students to engage in collaboration. In the era of rapid educational change these dynamic systems can contribute to increase student engagement, learning results, and access to good education.

The importance of technology-based learning, digital literacy and pedagogical innovations further has been emphasized in the National Education Policy (NEP) 2020 and other policies implemented in various parts of the world. Smart classrooms, virtual laboratories, learning management systems and IoT educational tools are increasingly gaining the attention of the educational institutions. However, factors such as digital readiness, teachers' skills, privacy concerns, digital tools and infrastructure are yet to pose a challenge in the successful implementation of these.

This study is thus justifiable since it aims to explore how IoT and ICT can help to create learning environments which are adaptive and intelligent to face the challenges of today's learning environment. The study draws upon the existing body of knowledge by exploring the potential use of technology for teaching, barriers to the use of technology, and implications for the future of technology in education. These outcomes can be used to inform the development of digital learning ecosystems for technology developers, institutional administrators, policy makers, and educators in creating a learner-centred approach to education and sustainable education.

Furthermore, the study has relevance as it highlights the dynamic interaction of technology and pedagogy and suggests some insights into the evolution of a smart learning environment to inspire innovation, inclusiveness, flexibility and lifelong learning. The opportunities and potential of the integration of IoT-ICT in educational environments and some of the key suggestions for the improvement of effectiveness, efficiency and flexibility of contemporary education are discussed.

### ***Objectives of the Study***

1. To explore the notion and importance of smart learning environments in today's education.
2. To understand how the Internet of Things (IoT) technologies can contribute to improving teaching, learning and classroom management.
3. To determine the role of Information and Communication Technology (ICT) tools for adaptive and personalized learning.
4. Explore how IoT and ICT technologies can be used to develop learner-centered, data-enabled learning spaces.
5. To determine the advantages and the problems

that can arise in the implementation of the smart learning system in educational institutions.

### **LITERATURE REVIEW**

Smart learning environments have a strong attractiveness in the context of the development of Information and Communication Technology (ICT) and the Internet of Things (IoT). Smart learning environments combine different kinds of digital technologies, sensors, intelligent devices, and data-driven systems, which can provide personalized and adaptive learning experiences. These settings enable students to interact with one another in real time, monitor their progress, and receive tailored feedback and learning plans, which boost engagement and learning outcomes. The convergence of IoT and ICT has been identified as an important trend recently and has made traditional classrooms into smart learning environments which can adapt to the individual needs and preferences of learners.

Mishra and Koehler (2006) state that successful technology integration in school learning entails technology, pedagogy and content knowledge being aligned. They have developed a framework called Technological Pedagogical Content Knowledge (TPACK) that emphasizes the need for pedagogical knowledge and digital tools to be integrated with the right pedagogical approach. The study shows that technology should be used to facilitate pedagogical goals, not just to digitize traditional pedagogical approaches.

Gros (2016) noted that smart learning environments offer flexibility, interactivity and learner-centered approaches which facilitate learners to learn on their own. The author highlighted the role of digital technologies in enabling continuous assessment and adaptive instruction, which enables teachers to better meet the needs of all learners.

Smart learning is an educational paradigm that uses context-aware technologies for enabling personalised learning introduced by Hwang (2014). The study revealed that adaptive systems can evaluate the behaviour of the learner and give them tailored content, which leads to an enhanced academic performance and motivation.

The use of the Internet of Things (IoT) in education has been considered one of the main contributors to the development of adaptive learning systems. According to Spaho, Çiço, and Shabani (2025), the Internet of Things (IoT) is employed in education to develop learning environments based on connected devices, sensors, and real-time data analysis to provide personalized learning. They pointed out that IoT technologies have the potential

to facilitate context-aware learning by adjusting the content to be delivered, the speed at which it is presented, and how it is presented to meet the individual learner's and the environment's characteristics.

Likewise, Tsipianitis et al. (2025) reported that the use of the IoT-based learning environment is markedly beneficial for students' motivation, self-directed learning and engagement. Their systematic review found that the use of smart objects, sensor networks, and connected devices enable experiential and personalized learning experiences, enhancing the learning process to be more interactive and effective.

De Lima, Schlemmer and Morgado (2020) explored the use of IoT in education and found that data collected from inter-connected devices can be used to gain insights into the behaviour and performance of learners. The study indicated that IoT systems can help the teacher to make effective pedagogical decisions and provide targeted interventions to enhance learning outcomes.

Hasan (2025) pointed out that the implementation of smart education system using IoT technology has become a revolution for the education system due to the implementation of interactive and adaptive learning. The study highlighted the advantages of IoT technologies, such as improved communication, collaboration, resource management, and learner monitoring, which can aid in both academic and administrative aspects of educational institutions.

Badshah et al. (2023) carried out a review of transition from conventional education to smart education and concluded that the incorporation of ICT, IoT and AI play significant role in the engagement of students, monitoring of attendance, assessment and classroom management. The research suggested that smart educational solutions can overcome many shortcomings of the conventional teaching methods and can provide rich learning experiences.

As per Ibrahim and Kenwright (2022), smart classrooms using IoT technology enable teachers to track students' engagement, gather learning data, and adapt their teaching methods on the fly. The results indicate that smart learning technologies can help with adaptive learning by detecting individual learning patterns and enable personalized interventions.

UNESCO (2018) highlighted that when dealing with technology integration, educators need to have ICT competencies. The framework emphasized the importance of technology-supported learning experiences for teachers in fostering creativity,

collaboration and critical thinking among learners. Similarly, Redecker (2017) emphasized the importance of developing digital competence in order to gain from the new educational technologies.

Notably, in recent systematic reviews, it was highlighted how intelligent educational technologies has become a relevant aspect in adaptive learning environments. Kerimbayev et al. (2025) discovered that intelligent education technologies help teachers predict students' achievement, aid in decision-making based on data, and facilitate individual education. By the end of the study, it was found that intelligent systems play a key role in helping to involve the learners and make their learning effective, if their use is appropriate in the learning process.

Overall, the literature suggests that IoT and ICT technologies could be a major enabler in the creation of smart learning environments. Previous research shows that adaptive education systems are effective at increasing learner interest, boosting learning outcomes, enabling tailored instruction, and managing education. But there are concerns about technological access, technological literacy, data privacy and infrastructure, all of which warrant further research.

## MATERIAL AND METHODOLOGY

### *Research Design:*

This study uses descriptive and exploratory research design to explore the role of Internet of Things (IoT) and Information and Communication Technology (ICT) in building smart learning environment which can support adaptive education. The research areas include the understanding of the role of the digital technologies, connected devices, intelligent learning systems and data-driven educational platforms in personalized learning, in engaging learners and in achieving academic success. Both quantitative and qualitative perspectives of technology integration in the education setting are dealt with through a mixed-methods approach. The study is a combination of primary and secondary data sources, which provides an overall evaluation of the opportunities and challenges of smart learning environments.

### *Data Collection Methods:*

Primary and secondary data is used for the study. Primary data was gathered by using structured questionnaires to the teachers, students, educational administrators and ICT coordinators of the schools, colleges and universities where technology-enhanced learning practices are

implemented. Emphasis on the participants' experience regarding the use of IoT devices, learning management systems, virtual classrooms, adaptive learning platforms, digital educational resources. Besides, selected educators and technology experts are interviewed and discussed regarding the effectiveness of the smart learning technology and how it affect the teaching and learning process.

Secondary data are collected from scholarly journals, books, conference proceedings, governmental reports, policy documents, institutional publications and trustworthy online databases on the topic of educational technology, IoT application, ICT integration, smart classrooms, adaptive learning systems, and digital education. These resources give the theoretical basis and context on which to build the study.

### ***Inclusion and Exclusion Criteria:***

Students, teachers, academic administration, educational technology specialists and institutions that actively use IoT devices, ICT tools or digital learning platform for the educational activities are included in the study. The review includes research articles, policy documents, and publications directly related to the smart learning environments, adaptive education, educational technology, IoT, and ICT integration. The study includes people with a range of educational levels to capture a wide variety of views on technology supported learning.

Those who have limited exposure to digital learning technologies, or those who do not participate directly in technology-supported educational activities are not included in the study. Only publications that can be considered as academically credible and relevant to adaptive learning, IoT and ICT in education are considered, thus excluding incomplete reports, publications that are not academically credible and duplicate studies.

### ***Ethical Considerations:***

Research process follows standards of ethics. All respondents are asked for informed consent prior to data collection and participation in surveys and interviews is optional. The purpose of the research is explained and participants are assured that their answers will be confidential and for academic research only. There is no sharing of personally identifiable information and the information is used in aggregate to preserve the anonymity of participants. All secondary sources are appropriately cited and acknowledged to guarantee academic integrity and to prevent plagiarism. The research is

carried out in an ethical, transparent and respectful manner with all participants, including the rights and dignity of the participants.

## **RESULTS AND DISCUSSION**

### ***Results:***

The study focused on the effectiveness of the use of Internet of Things (IoT) and Information and Communication Technology (ICT) tools in the establishment of adaptive learning environment. A total of 200 respondents consisting of students, teachers and educational administrators from higher education institutions that use digital learning technologies were considered. The results reveal that the implementation of IoT-based smart classrooms definitely increases student interest, individualized learning, academic achievement and satisfaction during the learning process.

***Table 1: Demographic Profile of Respondents***

Category	Frequency	Percentage (%)
Students	140	70.0
Teachers	45	22.5
Administrators	15	7.5
Total	200	100.0

### ***Interpretation***

Most of the respondents were students (70%), teachers (22.5%) and administrators (7.5%). This distribution is a collection of a variety of views on the implementation and effectiveness of smart learning environments.

***Table 2: Awareness of IoT and ICT-Based Learning Technologies***

Response	Frequency	Percentage (%)
Highly Aware	82	41.0
Aware	73	36.5
Moderately Aware	30	15.0
Less Aware	10	5.0
Unaware	5	2.5
Total	200	100.0

### ***Interpretation***

Three-fourths of respondents (77.5%) were aware or very aware of IoT and ICT technologies in education. This is indicative of the increasing adoption of digital learning tools in educational setting.

***Table 3: Perceived Impact on Student Engagement***

Level of Agreement	Frequency	Percentage (%)
Strongly Agree	96	48.0
Agree	70	35.0
Neutral	18	9.0
Disagree	10	5.0
Strongly Disagree	6	3.0
Total	200	100.0

### Interpretation

83% agreed that the student engagement was enhanced in smart learning environments due to the use of IoT. Interactive devices, digital collaboration tools and real-time feedback systems seem to encourage active engagement in learning activities.

**Table 4: Improvement in Personalized Learning Experience**

Response	Frequency	Percentage (%)
Excellent Improvement	78	39.0
Significant Improvement	72	36.0
Moderate Improvement	30	15.0
Slight Improvement	14	7.0
No Improvement	6	3.0
Total	200	100.0

### Interpretation

About 75% of respondents felt that there was excellent or significant improvement in personalised learning experiences. The use of IoT sensors and ICT platforms, in combination with adaptive systems, allows for individual teaching and tailored learning trajectories.

**Table 5: Impact on Academic Performance**

Response	Frequency	Percentage (%)
Highly Improved	68	34.0
Improved	81	40.5
Moderately Improved	31	15.5
No Significant Change	14	7.0
Declined	6	3.0
Total	200	100.0

### Interpretation

The results indicate that 74.5% of the respondents felt their academic performance improved since smart learning technologies were adopted. Better learning outcomes were achieved as a result of the continuous assessment and adaptive feedback mechanisms.

**Table 6: Challenges in Implementing Smart Learning Environments**

Challenge	Frequency	Percentage (%)
High Infrastructure Cost	65	32.5
Lack of Technical Skills	48	24.0
Data Privacy Concerns	36	18.0
Connectivity Issues	29	14.5
Resistance to Change	22	11.0
Total	200	100.0

### Interpretation

The highest cost of the infrastructure (32.5%) and lack of technical skills (24%) were identified as the greatest problems. The results indicate a need for greater funding in educational technology and for teachers in a holistic training program.

### Discussion:

The results show that the use of IoT and ICT technologies positively affects the effectiveness of adaptive education. The percentages of respondents who stated they were very aware of educational institutions are high, suggesting that digital transformation is more and more taking hold in these institutions. The findings also show that the smart learning environment can promote students' engagement by providing interactive learning activities and learning activities empowered by technology.

The paper also recognizes the important role played by adaptive systems based on IoT in personalized learning. Intelligent devices, learning analysis and automatic feedback systems allow teachers to adapt teaching methods to students' needs. This is in line with the current trends in pedagogy that stress the learner and competency-based learning.

Evidence of academic improvement indicates that smart learning environments support continuous monitoring, assessment and timely intervention. The students get instant feedback and the teacher gets valuable feedback regarding the student's learning patterns and progress. These skills help to make more informed decisions when teaching and enhance learning.

In spite of these advantages, there are challenges for implementation. Large scale adoption continues to be challenged by infrastructure costs, digital skills shortages, privacy issues and connectivity constraints. Therefore, educational institutions need to invest in technological infrastructure, teacher training, cybersecurity and digital literacy programs in order to optimize the benefits of smart learning ecosystems.

In summary, the results support the belief that the application of IoT and ICT technology plays a crucial role in the fields of adaptive education, as it helps to enhance learning performance, personalization and engagement; and the need for strategic planning to overcome the implementation challenges.

### Limitations of the study

A few limitations of this study exist, and should be taken into account when interpreting the results. Research is mainly related to the use of Internet of Things (IoT) and Information and Communication Technology (ICT) instruments in smart learning environments, which might have a constraint in generalizing the conclusions to schools that have a proper technological infrastructure. Internet connectivity, smart device

availability, and students' and teachers' digital literacy can differ, affecting the effectiveness of adaptive learning systems and not being equally distributed throughout the educational system. The study is based on the responses obtained from the selected participants that could be affected by the perceptions, experiences and familiarity of the participants with the educational technologies. Moreover, the developments of IoT applications and artificial intelligence, and digital learning platforms, could mean that various technologies are undergoing changes that may not be reflected in the scope of the research period. Financial considerations, institutional policies, concerns about data privacy and smart learning technologies' cyber security are recognized but might not be explored in depth. Despite the limitations, this study has been able to come up with some insights into the opportunities and difficulties encountered in the adaptive education using IoT and ICT, and also served as a stepping stone for future studies on the new field of adaptive education for IoT and ICT.

### *Future Scope*

The future of smart learning environments is one where the Internet of Things (IoT), Information and Communication Technology (ICT), Artificial Intelligence (AI) and data analytics converge to deliver highly personalized and adaptive learning environments. Future research may focus on creating the intelligent learning system that continuously captures students' learning behaviours, their engagement, and academic performance by using interconnected devices and sensors. More focus can be given to designing inclusive and accessible learning contexts to meet the needs, abilities and backgrounds of learners. The effectiveness of the IoT enabled classrooms for improving collaborative learning, critical thinking, and problem solving at various educational stages can be explored by researchers.

Future research could address issues of privacy and security in data, ethical issues related to learners' data, digital equity in smart learning ecosystems and others. Advanced technology like augmented reality, virtual reality, edge computing and generative AI open the way to immersive and interactive learning experiences. Regional, institutional and disciplinary comparative studies can contribute to understanding the scalability and sustainability of smart learning initiatives. While education systems are still in the process of digital transformation, future studies should also focus on

the policy and teacher readiness and institutional approaches required for the effective implementation of adaptive learning technologies, in order to contribute to the improvement of education systems for the future, based on effective learning and adapting learning.

### **CONCLUSION**

The use of Internet of Things (IoT) and Information and Communication Technology (ICT) is driving the shift from conventional learning environments into adaptive, interactive and learner-centred smart learning environments. When combined these technologies enable customization of learning for diverse student needs, learning styles and academic skill, by capturing real-time data, offering cloud-based platforms and adopting intelligent learning technologies.

The study points out that the use of data in education in S.L.E has been proven to be beneficial for teachers' effectiveness, students' engagement, continuous assessment and decision-making in education. ICT tools promote collaboration, communication and access to learning opportunities outside the classroom walls whilst Internet of Things (IoT) enabled devices provide real-time monitoring of learning activities. These technologies are embedded in a world that is adaptive, flexible and inclusive – where the needs of the modern educational environment, and those of the students within it, are met.

Although there are many benefits that come with this, several challenges hinder the implementation, such as low technical literacy of teachers, concerns about data privacy and security, high implementation costs, and inadequate digital infrastructure. Strategic investment in infrastructure, comprehensive training of teachers, supportive educational policies, as well as strong data protection structures, all need to be invested in to address these barriers.

The success of adaptive education hinges on the successful use of new technologies along with effective pedagogy. It is important to establish a collaboration among education, policy and technology to build sustainable equitable and technology-rich learning environment. With the support of IoT and ICT, smart learning environment can further enhance the learning outcomes, and support lifelong learning to promote students' participation in a knowledge-based and connected society, by which digital transformation will further drive the change of the education.

## REFERENCES

1. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, 17(4), 2347–2376. <https://doi.org/10.1109/COMST.2015.2444095>
2. Anderson, T. (Ed.). (2008). *The theory and practice of online learning* (2nd ed.). Athabasca University Press.
3. Bates, A. W. (2022). *Teaching in a digital age: Guidelines for designing teaching and learning* (3rd ed.). Tony Bates Associates Ltd.
4. Bdiwi, R., de Runz, C., Faiz, S., & Cherif, A. A. (2019). Smart learning environment: Teacher's role in assessing classroom attention. *Research in Learning Technology*, 27, 2072. <https://doi.org/10.25304/rlt.v27.2072>
5. Bonk, C. J., & Graham, C. R. (Eds.). (2012). *The handbook of blended learning: Global perspectives, local designs*. Pfeiffer.
6. Chatti, M. A., Muslim, A., Schroeder, U., & Wosnitza, M. (2014). Learning analytics: Challenges and future research directions. *eLearning Papers*, 36, 1–6.
7. Cope, B., & Kalantzis, M. (2017). *e-Learning ecologies: Principles for new learning and assessment*. Routledge.
8. Dede, C. (2014). The role of digital technologies in deeper learning. *Students at the Center: Deeper Learning Research Series*. Jobs for the Future.
9. Dey S. M. (2021). Psychosocial stress contagion of COVID-19: issues and intervention channels. *Ensemble SP-1*, 44–53. <https://doi.org/10.37948/ensemble>
10. Dey, S. M. Women & children trafficking in Bangladesh: A historical significance & current challenges.
11. Dey, Sourav (2012). "Discursive Self in Consumption: Body, Fluidity, and Femininity". *Global Media Journal, Indian Edition* 3 (1), pp. 1-12.
12. Garrison, D. R., & Vaughan, N. D. (2013). *Blended learning in higher education: Framework, principles, and guidelines*. Jossey-Bass.
13. Hwang, G. J. (2014). Definition, framework and research issues of smart learning environments – A context-aware ubiquitous learning perspective. *Smart Learning Environments*, 1(1), 4. <https://doi.org/10.1186/s40561-014-0004-5>
14. Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in education. *Computers and Education: Artificial Intelligence*, 1, 100001. <https://doi.org/10.1016/j.caeai.2020.100001>
15. International Society for Technology in Education. (2017). *ISTE standards for educators*. ISTE.
16. Koper, R. (2014). Conditions for effective smart learning environments. *Smart Learning Environments*, 1(1), 5. <https://doi.org/10.1186/s40561-014-0005-4>
17. Kukulska-Hulme, A. (2020). Mobile-assisted learning and future educational technologies. *ReCALL*, 32(2), 157–171. <https://doi.org/10.1017/S0958344020000010>
18. Luckin, R. (2018). *Machine learning and human intelligence: The future of education for the 21st century*. UCL Institute of Education Press.
19. Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research. *Computers & Education*, 56(3), 769–780. <https://doi.org/10.1016/j.compedu.2010.10.020>
20. Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054.
21. N. BN, D. E. Geetha and R. G, "Parametric and Non-Parametric Analysis on Metaheuristic Based Event Recommendation System," 2025 Control Instrumentation System Conference (CISCON), Manipal, India , 2025, pp. 1-10, doi: 10.1109/CISCON66933.2025.11337415.
22. N. BN, S. B. Murthy and S. DS, "Improved Quantum Neural Network for Intrusion Detection and Blowfish for Data Security," 2025 Control Instrumentation System Conference (CISCON), Manipal, India , 2025, pp. 1-9, doi: 10.1109/CISCON66933.2025.11337273.
23. Nithya BN, Hemanth Uppala,(2026). Intrusion detection with improved quantum neural network: A bigdata perspective. *Future Generation Computer Systems*, Vol-175. DOI: <https://doi.org/10.1016/j.future.2025.108102>
24. OECD. (2021). *Digital education outlook 2021: Pushing the frontiers with artificial intelligence, blockchain and robots*. OECD Publishing.
25. Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union.

26. Romero, C., & Ventura, S. (2020). Educational data mining and learning analytics: An updated survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 10(3), e1355. <https://doi.org/10.1002/widm.1355>
27. Selwyn, N. (2016). *Education and technology: Key issues and debates* (2nd ed.). Bloomsbury Academic.
28. Spector, J. M. (2014). Conceptualizing the emerging field of smart learning environments. *Smart Learning Environments*, 1(1), 2. <https://doi.org/10.1186/s40561-014-0002-7>
29. UNESCO. (2018). *ICT competency framework for teachers* (Version 3). UNESCO Publishing.
30. UNESCO. (2023). *Guidance for generative AI in education and research*. UNESCO Publishing.
31. Uskov, V. L., Howlett, R. J., & Jain, L. C. (Eds.). (2015). *Smart education and smart e-learning*. Springer.
32. Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & Van Braak, J. (2013). Technological pedagogical content knowledge—A review of the literature. *Journal of Computer Assisted Learning*, 29(2), 109–121. <https://doi.org/10.1111/j.1365-2729.2012.00487.x>
33. Wang, S., & Huang, R. (2018). Building smart learning environments with the Internet of Things. *Educational Technology Research and Development*, 66(3), 779–803.
34. Williamson, B. (2017). *Big data in education: The digital future of learning, policy and practice*. Sage Publications.
35. Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, 16(1), 39. <https://doi.org/10.1186/s41239-019-0171-0>
36. Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments*, 3(1), 4. <https://doi.org/10.1186/s40561-016-0026-2>