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Reviewing IoT Implementation in Pakistan's Education Sector: Opportunities and Challenges

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***Abstract*—The Internet of Things (IoT) is acting as a catalyst for educational change in Pakistan. IoT integration in education has a great impact on diverse stakeholders such as faculty, students, administrators, management, parents, government, policy makers, technology providers, community, society and NGOs. This study aims at reviewing the effects of IoT implications in the education sector of Pakistan. This paper provides comprehensive review related to opportunities of IoT which it gives to educational institutions and all the relevant stakeholders involved. This review paper also sheds the light on challenges that educational institutions, specifically in Pakistan, face when implementing IoT in their daily activities. Moreover, IoT is likely to impact classroom dynamics through the use of smart devices such as those that facilitate the real-time collection and analysis of data, aiding to personal teaching approach that complements the diverse learning needs and paces. On the administrative side, IoT helps in the efficient management of school resources, security, and energy consumption, which leads to cost reductions and improved educational outcomes. The benefits as well as the issues need to be covered together and this creates a balanced view that can guide all the stakeholders who are looking for IoT adoption in the education field.**

***Keywords*—IoT in Education, Interactive Learning, Administrative Automation, Digital Divide, Privacy Concerns, Operational Efficiencies, Smart Devices, Resource Management and Cost Reductions**

I. INTRODUCTION

THE integration of the Internet of Things (IoT) in our everyday life has improved our living standards [7]. The applications of the Internet of Things have already implemented in various fields such as medical, retail, customer service, industries, smart cities, and environmental monitoring [5]. The main idea behind the Internet of Things is to make smarter versions of daily-use objects. Communication is carried out among devices through the internet which includes capabilities of processing, network, identification, controllers and different sensors [1]. A wide range of review papers has been written down on the use and applications of IoT in different domains [6]. Due to the increasing demand for IoT devices, the education sector all over the world is integrating IoT in educational activities. It has revolutionized educational institutions. It has given a new way of learning and teaching environment. According to one study, IoT in education will be a game-changer [2].

IoT in Pakistan's education sector plays a powerful role, especially after COVID-19 era. During the pandemic, the Pakistani education sector lacked many useful skills like online teaching experts, digital experts, and resources required for online education. It created lots of challenges to implement IoT in education mainly in remote areas of the country (Fig. 1). Learners and educators had to take the online lectures forcefully. This type of educational transformation was happening first time in Pakistan where all educational institutions, irrespective of their levels, were asked to deliver online lectures through different applications like WhatsApp, Google Meet, Google Classroom,

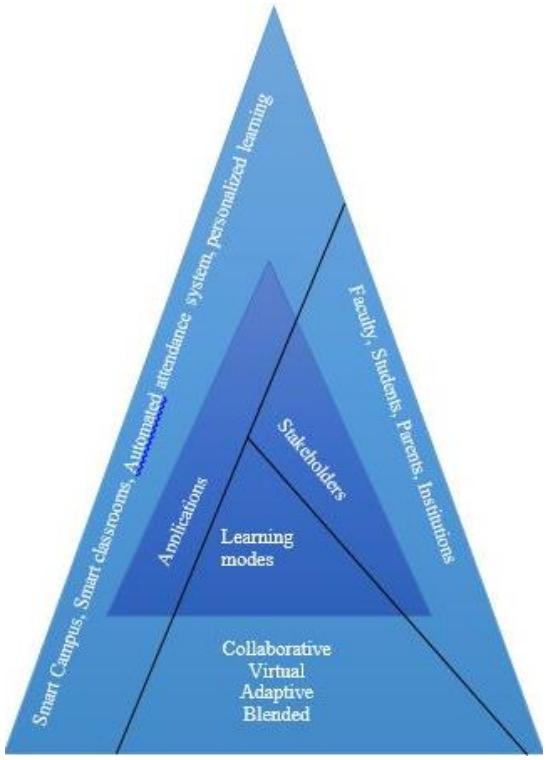

Fig. 1: The 3-D impact of IoT on education.

Zoom, etc. [3]. That was such a challenging era for Pakistani educationists and learners, as according to one report published by the Pakistan Telecommunication Authority, only 36.86% of the population in Pakistan had access to broadband internet [3], [4]. IoT involves educational transformation at all levels including the early years of schooling, lower primary, upper primary, secondary, higher secondary, graduate, and post-graduate. The adoption of IoT in Pakistan's educational institutions is not without its challenges. Foremost among these are infrastructural deficiencies, including inconsistent power supply and inadequate internet coverage, which impede the deployment of IoT solutions.

Financial constraints further complicate this scenario, with limited budgets available for up-front investments in technology. Additionally, there is a noticeable gap in digital literacy and technical skills among educators and administrators, which slows the adoption and effective use of IoT technologies.

II. Background

The Internet of Things (IoT) is a dramatic technology innovation that is simplified as the interconnection between all the daily life objects which are communicating and sharing data among themselves. In the sphere of education, IoT has proven itself as the most transformative technology facilitating novel ways to improve the performance of the processes and to ease the burden of the administrative tasks. Introduction of IoT technology, like sensors, smart boards, and wearable devices in education settings brings the learning environment alive and challenges it to be more active and responsive. Through this technology not only routine tasks can be automated, but this technology also provides essential data that can monitor students' attention, progress and support the improvement of the teaching strategies and learning outcomes [9].

A. Significance

The educational value of IoT cannot be understated, as it holds the promise of personalized learning and the provision of equitable means of learning. IoT system empowers educational organizations to come past usual restrictions that result from environmental and resource factors. In underdeveloped countries with wide educational gaps like Pakistan, the Internet of Things (IoT) connection presents a platform to promote quality education beyond the bounds of existing systems. The immediate data from IoT devices assist administrative personnel in making objective-based and thought-through decisions, therefore ensuring efficiency and proper timing of resource utilization and any designed intervention programs. Furthermore, along with IoT the educational experience is improved by building students' and expectants digital capacities so that they would be able to cope in the Internet age.

III. Opportunities

The use of Internet of Things technologies (IoT) in the education sector of Pakistan offers countless chances to give a 180-degree turn to the traditional educational systems [6]. The IoT presents great opportunities to improve the classroom learning environment through the creation of smart classrooms, the development of real-time student monitoring, and personalized learning. In Pakistan where educational institutions face an overwhelming workload, IoT will help to optimize the usage of resources, cut operation amount spent, and enable distance learning which will be favorable for the remote and under-serving areas. Amplified data collection and processing via IoT devices may help teachers to have a grasp of students' engagement and performance which might directly contribute to minimized educational shortages.

Talking of the opportunities provided by IoT technology in the education realm one can note that there are many ways of improving the educational process and learning in the schools. Use of smart devices and IoT app to classrooms help in creation of interactive and involving learning spaces for children. IoT allows constructing of clever campuses that are able to manually monitor devices and turn off devices like lights and heating when they are not in use, thus creating a sustainable environment at minimum expenditure. Besides, the IoT is also a great tool for personalized learning experiences- it offers the option to measure individual learning habits and tastes based on data collection and analysis.

A. Advantages

The number of benefits that come with the deployment of the IoT is numerous. First, this all directs towards a creative method of schooling, which uses digital devices combined with on-the-spot data that innovate the rather traditional way of teaching. IoT supporting the improvement of educational outcomes is a process that is based on the real-time monitoring and targeting of students who are at risk of negative school performance. Additionally, the situation of Internet of things (IoT) augments the safety and security of educational institutions through smart surveillance and access control systems. They protect students and staff health and safety, so a comfortable, safe learning environment must be provided Humanize the given sentence. Instruction: Indicate how the sentence can be improved. Initiatives such as eco-friendly transportation methods and energy-efficient infrastructure are being implemented to reduce greenhouse gas emissions [9].

IV. Challenges

IoT, despite that, not does go without saying that execution in Pakistan, however, has been faced with specific challenges. Difficulties are arising, such as the lack of infrastructure, for example, the absence of Internet connection and the use of outdated educational facilities, which complicate the usage of IoT application solutions. Moreover, there are issues of user data privacy and data security issues that arise when the number of devices connected to the IoT is increased as it increases the risk of attacks and data breaches. Nevertheless, there are costs associated with the deployment of the Internet of Things technologies as well. Furthermore, private schools with less budget may find it difficult to afford. In addition, there is a feeling for the provision of training and development courses to help educators and putty staff in their proficient skills for using Internet of Things (IoT) technologies effectively [6].

A. Solution

Since there is a set of problems, some possible solutions can be presented. Implementation of enhanced cybersecurity controls is a priority; academic organizations should allocate funds for security systems, and those network should be checked on regular basis, to achieve the goal of network protection. Governments and the community sector should ensure that everyone has the same access to digital resources by providing funds and cutting down on costs for schools without enough money for technology. Teachers and other non-technical staff needs to have programs that will train them on how to use the IoT devices and data management so that the technology can be efficient and end result qualified. Moreover, pursuing a staged approach to the introduction of IoT system can afford a way for managing costs such that the institutions scale up adoption of IoT gradually with funds and achieved services.

V. Human Resources Involved In Smart Education

A. Educational Staff And Teachers

In a smart education system, the human resources that constitute its core are the educators and experts in their respective fields. Their work scope in such noteworthy settings sees a drastic shift increasingly. The teachers perform as the senders of materials and the modifiers of technology-based instructional techniques. They should incorporate IoT tools modestly into their classwork, which will finally lead to specialized programming for the teachers. Among the key skills that need to be cultivated is the proper harnessing of the IoT, which is not to replace the traditional methods of teaching, but just to make sure that education is rather transformed and enhanced using the technology [15].

B. IT And Technical Support Staff

Consequently, the importance of promoting sustainable practices and technologies to minimize pollution, reduce waste, and enhance resource efficiency cannot be overstated.

Effortless implementation and effective upkeep of Internet of Things devices and networks on academic campuses can be achieved by a combination of in-house IT and technical support staff. This team implements the IoT infrastructure, deploying the devices, configuring, and conducting maintenance. It makes sure that the system is secure and all the elements are functioning correctly. The area of expertise by IT specialists is also critical in the event of a technical issue by a teacher or student, otherwise, they can resolve the issue quickly and continue with the teaching process [16].

C. Administrative And Managemnent Staff

Management and administrative staff in educational institutions will have a central role in the transformation of the educational process by means of the IoT application. They are in charge of identifying the IoT technology that should be deployed, of monitoring the processes, of allotting budgets, and ensuring to comply with the data protection laws. These top staff will serve as the fundamentals of IoT aims on aligning with educational objectives besides the investment in technology producing positive results in the education.

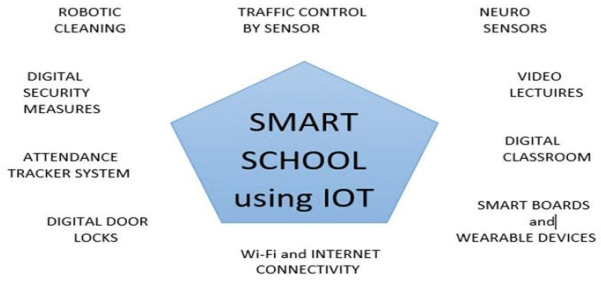

Fig. 2. Paradigm of Smart Education with IoT approach

TABLE I: TABULAR FORM OF IOT IN EDUCATION

Aspect	Description
Definition	IoT involves upgrading everyday objects with identification, sensor, network, and processing capabilities, enabling communication via the Internet. Smart objects require minimal human intervention for data generation, exchange, collection, analysis, and management [7].
Opportunities	- Enhanced learning environments in smart classrooms. - Efficient campus management through IoT devices. - Improved student engagement using wearable tech and interactive tools [6].
Challenges	- Data Privacy and Security: Protecting student data. - Infrastructure and Connectivity: Reliable networks for successful IoT implementation. - Faculty Training: Educators need training to integrate IoT effectively [6].
National Curriculum	The National Curriculum of Pakistan 2022-23 emphasizes IoT in technical education. Learning outcomes include understanding IoT concepts, designing solutions, and applying them practically [8].
Impact of IoT-Based Labs	Smart laboratories enhance practical learning experiences. Challenges include cost, maintenance, and faculty readiness [6].

VI. Research Methodology

A. Overview

Most researchers use methodologies for studying the integrated and impacted role of the Internet of Things (IoT) in education by choosing a mixed method of qualitative and quantitative studies. This multimethod approach ensures a comprehensive analysis of the measurable outcomes from one side and the more subtle feedback gained directly from participants who are in IOT-enhanced education settings.

1) Quantitative Methods

For the sake of this discussion, the use for the collection of data can include the administration of surveys and pre-posttest measures to gauge the efficacy of the IoT by way of its impact on the improvement of educational outcomes. This study observed standardized testing results among students who took the tests before and after the introduction of IoT devices to find out the rates of improvement. Besides, statistical analysis will

be the tool for evaluating the school operations efficiency increase because of the IoT integrations into the system [15].

2) Qualitative Methods

One of the competencies of qualitative research methods examples of which include interviews, focus groups, and case studies in understanding the sensitivity and subjective experiences of education workers and students with IoT in education is another important tool. Teachers' feedback on IoT tools can help in gaining an understanding of how these tools have altered their teaching methods, as well as the challenges they face in adjusting to new technologies. Focus groups with students can be valued in providing insight into how IoT influences the students' learning experience, and level of engagement [16].

3) Mix Methods Approach

The classic pairing of methods makes use of case studies or face-to-face interviews, often in combination with surveys. This method gives an opportunity for researchers to raise complete conclusions on the IoT adoption in schools and its actual impact on learning outcomes. A synthesized approach that uses both types of data can bring better awareness of the implications of IoT applications in the field of education. On the one hand, it provides objective criteria and, on the other hand, a platform for participants to share their lived experiences.

TABLE II: PROTOCOLS USED IN IOT FOR EDUCATION

Protocols	Description	Application in Education	Advantages
MQTT	Lightweights publish-subscribe messaging protocol.	Real-time data transmission between IoT devices and servers. Efficient communication in smart classrooms, campus management, and student tracking.	-Low overhead and minimal bandwidth usage - Reliable message delivery -Scalability for large-scale deployments.
CoAP	Designed for constrained devices and low-power networks. Operates over UDP.	Suitable for IoT devices in educational settings. Used for sensor data exchange, device discovery, and control.	-Minimal overhead - Supports resource discovery -Designed for constrained environments
HTTP	Widely used for communication between web servers and clients.	Used for web-based interfaces in smart classrooms, student portals, and administrative systems. Enables interaction with IoT devices via web APIs.	-Familiarity and widespread adoption -Supports RESTful APIs -Works well with existing infrastructure
DDS	Middleware protocol for real-time data distribution and communication.	Used for complex IoT scenarios, such as collaborative learning environments. Supports high-performance data exchange.	- Publish-subscribe model -Scalability and reliability -QoS (Quality of Service) customization

VII. RELATED STUDIES CLASSIFICATION

Based upon studies we have conducted; we attempt to map the seamless relationship between the IoT in Education.

A. Overview

The Internet of Things research (IoT) for education purposes can be broken down into numerous studies, which do the investigation of different aspects of its application. The classification of these studies can be broadly segmented into three main categories: adoption, advancing teaching techniques, and setting up administrative matters.

1) Technological Implementation

Research in the category of 'Hardware and software' of IoT systems mainly aims at illustrating pieces of equipment and software applications that are characteristic of educational settings. Critical sectors include giving sensing and system tools a look as well as network security and data maintenance. As such, smart classrooms [7] report on IoT-based technologies that improve education infrastructure and highlight in completing their implementation, the intertwined technical difficulties faced.

2) Pedagogical Outcomes

Here is the area that the research concentrates on the IoT devices' effect on the medium of teaching and the way learners acquire the knowledge. More precisely, the research is purposed to determine how the Internet of Things technologies influence learners' outcomes, their strong commitment to study, and grade personalization. According to [16], the Internet of Things not only changes how students learn but also serves as a transforming agent of the educational process by bringing about a new form of interaction between students and educational content as well as between students themselves.

3) Administrative Efficiency

Studies under this classification contain research about how myriad applications of IoT can be brought in to take the management and operational aspects of educational institutions to new heights. Issues like campus security, resource management, and campus energy efficiency had been discussed. In their article named "IoT in optimizing resource allocation and reducing operational cost: key for achievements in education management", Singh and Masilamani suggested that IoT may be used to optimize the allocation of resources, and thus, reduce operational expenses, which are essential to ensure quality in education.

VIII. SMART DEVICES IN EDUCATIONAL INSTITUTIONS

The integration of smart devices in educational institutions offers a transformative potential to enhance both the teaching and learning environments. According to a comprehensive review by this paper [6], smart devices such as interactive whiteboards, wearable technology, and personalized learning systems are instrumental in creating dynamic and interactive classrooms. These technologies not only facilitate a more engaging learning experience but also allow for the monitoring of student engagement and performance in real-time.

TABLE III: LITERATURE REVIEW

Author(s)	Year	Geographic Focus	Study Focus	Key Findings	Methodology	Relevance to Pakistan
Chaudhry et al. [13]	2022	Pakistan	Teacher training for IoT integration	Identified a significant gap in digital literacy and technical training among teachers, affecting IoT adoption rates.	Qualitative interviews; thematic analysis	Highlights the need for targeted professional development programs in IoT technology across Pakistan, particularly for sustainable adoption.
Smith et al. [12]	2021	USA	Impact of IoT on student engagement	IoT applications led to a 40% increase in student engagement through interactive and adaptive learning tools.	Quantitative survey; statistical analysis	Suggests potential methods to enhance engagement in Pakistani schools using IoT, considering urban settings similar to study context.
Lee [14]	2020	South Korea	Efficiency of IoT in school resource management	Implementation of IoT in schools led to a 30% reduction in energy costs via smart climate control and lighting systems.	Mixed methods; interviews and utility bill analysis	Demonstrates a successful model of resource management that could be adapted to Pakistani schools for cost savings and efficiency improvements.
Khan and Iqbal [10]	2019	Pakistan	Barriers to IoT adoption in rural schools	Critical infrastructural issues identified include intermittent electricity and unreliable internet services, significantly hindering IoT adoption.	Case studies; observational data	Directly addresses the challenges faced in rural Pakistan, offering groundwork for policy interventions and infrastructure upgrades.
Patel and Singh [15]	2018	India	IoT for improving school safety	Found that automated surveillance and access control systems enhanced overall school security and emergency responsiveness.	Case study; implementation review	Provides insights into security enhancements possible through IoT, relevant to improving safety measures in Pakistani schools.

In Pakistan, deploying of such smart devices faces challenges due to infrastructural limitations and financial constraints, as in this paper [10] noted. They point out that inconsistent electricity and internet reliability significantly hinder the adoption of IoT technologies in rural schools. Despite these challenges, the potential for improving educational outcomes through smart devices remains significant. For example, this [11] emphasizes incorporating IoT technologies to enhance technical education, suggesting a governmental recognition of their importance.

Furthermore, studies like those by [12] in the USA demonstrate that IoT applications can lead to a 40% increase in student engagement through interactive and adaptive learning tools, suggesting a model that could potentially be adapted in Pakistan to overcome barriers and improve engagement.

IX. CHALLENGES AND RESISTANCE TO SMART EDUCATIONAL PRACTICES

The adoption of smart educational practices, while promising, encounters several challenges and resistance particularly in developing regions like Pakistan. A primary concern is the infrastructural inadequacies, such as unreliable internet connectivity and power supply, which pose significant barriers to the effective use of IoT technologies in education. According to this [10] how intermittent electricity and unreliable internet services significantly impede the adoption of IoT in rural schools. Additionally, there is a substantial economic challenge as many educational institutions face budgetary constraints that limit their ability to invest in new technologies.

Another major hurdle is the resistance due to a lack of digital literacy among educators and administrative staff. This paper [13] identified a significant gap in digital literacy and technical training among teachers, which affects the rates of IoT adoption. This resistance is further compounded by concerns over data privacy and security, as the increase in connected devices raises the risk of data breaches and cyber-attacks.

To address these issues, targeted professional development programs and enhanced cybersecurity measures are essential. Moreover, there needs to be a concerted effort from both government and private sectors to improve the infrastructure and reduce the cost of technology to make smart educational practices more accessible and sustainable.

X. CONCLUSION AND FUTURE DIRECTION

In conclusion, the integration of IoT technologies into Pakistan's educational sector holds significant promise for enhancing teaching and learning environments. However, the effective implementation of these technologies faces substantial challenges, including infrastructural deficits, financial constraints, and a lack of digital literacy among educators. As noted by this paper [13], overcoming these barriers will require targeted professional development and substantial investment in educational infrastructure.

Looking forward, the focus should be on creating a robust framework that supports the widespread adoption of IoT technologies in education. This includes establishing reliable internet connectivity and power supply, particularly in rural and underserved areas, as highlighted by [10]. Furthermore, it is crucial to enhance the digital capabilities of educators through ongoing training programs, as identified by the given

paper [14] to ensure they are equipped to utilize and benefit from IoT technologies.

The potential for IoT to revolutionize the educational landscape is immense, particularly in improving educational outcomes and operational efficiency. With the right support and investments, the future of education in Pakistan through IoT looks promising and could serve as a model for other developing countries.

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