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Transforming Educational Institutions: Harnessing the Power of Internet of Things, Cloud, and Fog Computing

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Abstract: The Internet of Things (IoT), cloud, and fog computing are now a reality and have become the vision of the smart world. Self-directed learning approaches, their tools, and smart spaces are transforming traditional institutions into smart institutions. This transition has a positive impact on learner engagement, motivation, attendance, and advanced learning outcomes. In developing countries, there are many barriers to quality education, such as inadequate implementation of standard operating procedures, lack of involvement from learners and parents, and lack of transparent performance measurement for both institutions and students. These issues need to be addressed to ensure further growth and improvement. This study explored the use of smart technologies (IoT, fog, and cloud computing) to address challenges in student learning and administrative tasks. A novel framework (a five-element smart institution framework) is proposed to connect administrators, teachers, parents, and students using smart technologies to improve attendance, pedagogy, and evaluation. The results showed significant increases in student attendance and homework progress, along with improvements in annual results, student discipline, and teacher/parent engagement.

Keywords: Internet of Things; cloud computing; fog computing; smart institutions; learning experience; smart technologies

Citation: Badshah, A.; Rehman, G.U.; Farman, H.; Ghani, A.; Sultan, S.; Zubair, M.; Nasralla, M.M. Transforming Educational Institutions: Harnessing the Power of Internet of Things, Cloud, and Fog Computing. *Future Internet* **2023**, *15*, 367. https://doi.org/10.3390/fi15110367

Academic Editor: Ping Wang

Received: 8 October 2023
Revised: 3 November 2023
Accepted: 7 November 2023
Published: 13 November 2023

1. Introduction

Innovative and ubiquitous technologies have become not only a reality but also a vision for growth and improvement for future generations. Approximately 75 billion smart devices are projected to be connected to the network by the year 2025. Nanosensors and artificial intelligence (AI) are breathing life into these smart devices, allowing them to analyze data and make decisions. Likewise, the World Economic Forum (WEF) anticipates that the educational technology sector will reach a value of USD 342 billion by 2025 [1]. With the current needs of the digital world, educational institutions must transform into smart institutions by using smart technologies and the power of IoT. The integration of smart technologies and the Internet of Things (IoT) into educational institutions represents a significant step toward meeting the demands of the digital world and preparing students for the future. By embracing these technologies, institutions can enhance learning outcomes, improve resource management, and provide a more efficient and effective educational experience [2–4].

The three important pillars of an education system (from a decision perspective) are administrators, teachers, and parents. Similarly, the three important pillars of the learning process are students, teachers, and parents. The active participation and effective decision-making of all these stakeholders are crucial for the coming generation [5]. The smart institution framework (SIF) represents the first step toward facilitating stakeholders' active involvement, smart pedagogy, smart monitoring, and smart reporting [6].

Parents represent a cornerstone of the education system. Without parental interest and participation, student learning cannot be effective. It is a universal truth that the education system is as good as its teachers and administration vision. Teachers are nation builders who engage, motivate, and inspire students. Institutional administrators are the top stakeholders [7,8]. They make decisions based on reports and feedback to foster a productive teaching and learning environment for teachers and students, respectively. Providing the right information on the administrators' table is of prime importance for making the right decisions. For a good education system, it is necessary to optimize the productive engagement of all human elements according to the needs of educational institutions [9,10].

The teaching–learning process is not the same as it was years ago. Curriculum, pedagogy, teacher, and student thinking have evolved to Education 4.0 [11], which is sharply affecting all these aspects right down to their roots [12]. However, in developing countries, especially in remote schools, the proposed standard operating procedures (SOPs) are not properly followed, students and parents are not adequately engaged, nor is there transparent performance monitoring. There is no proper relationship management system between institutions and parents [6,13]. Table 1 shows a comparison between smart and traditional education systems.

Table 1. Comparison between smart education and traditional education.

Smart Education	Traditional Education
Flexibility is a key benefit of smart schooling. It enables students to study in their own environment. Teachers can be accessed as needed [14].	Traditional education is less adaptable. Students must attend classes in person [15].
Location and time are not factors in smart education. Students can access lessons anytime, anywhere [16].	Traditional education relies on specific locations and is bound by time constraints.
Smart education reduces operational costs through paperless work, reducing travel, testing, and administrative expenses.	Traditional education has higher operating costs, including paperwork, travel expenses, test costs, and administration fees.
Smart education enables educators to teach on a global scale, offering a diverse array of courses [17].	Traditional education relies on physical presence, limiting the variety of courses.
Smart education offers various collaboration and communication tools (e.g., Zoom [18], Google Meet [19], Skype [20]).	Traditional education necessitates a physical presence, incurring daily and travel expenses.
Smart education's deficiency in social interaction impacts the social and communication skills of students [21].	Traditional education promotes social learning through face-to-face interaction, improving social skills [15].
Smart education lacks extracurricular activities.	Traditional education provides extracurricular activities, enhancing students' readiness for learning [22].
While operational costs are minimized, smart education requires a significant capital investment for system installation.	Traditional education remains expensive overall.

The leading challenges to the traditional education system are as follows:

1. Educational technology (EdTech) has transformed teaching and learning methods. Teachers and learners follow outdated patterns that are not comfortable with cutting-edge innovations.
2. Traditional methods for monitoring employee and learner progress are time-consuming and do not ensure accurate information for decision-makers, which results in wrong decisions.

3. Similarly, management practices within the institution are antiquated, and these conventional approaches lack transparency in the reporting system.

Considering the aforementioned challenges, there is a pressing need for a smart system that effectively caters to the needs of administrators, teachers, parents, and students. We extended our framework to tackle the above issues and handle them smartly [8]. Smart institutions reduce costs and make transparent performance monitoring possible [23,24]. They improve the quality of education in ways that some might not have thought possible a few years ago. The proposed structure (as shown in Figure 1) has five key elements: administrators, teachers, parents, learners, and finally smart devices for connecting stakeholders. The SIF utilizes smart devices, fog, and cloud computing technologies to overcome most of the drawbacks of traditional education systems.

The following are the main objectives of this study:

1. To introduce Education Technology (EduTech) for teaching and learning to supersede outdated methodologies. The inclusion of innovative technologies is aimed at elevating the educational system to par with other systems that make extensive use of these technologies.
2. To propose an innovative solution to smartly monitor the progress of teachers and learners. This will help in generating real smart data. Decisions made on these true data will transform the educational system.
3. To utilize cutting-edge management technologies to smartly manage the institution and process the workload of months in hours.

The proposed model further extends existing schooling theories. The existing theories [7] focus on a student, teacher, and parent paradigm for effective learner engagement. However, these theories need to be revised to align them with current smart needs. Administrators are the lead members of schools. No matter how hard the teachers put in their efforts, if the administrators are not in sync, the learners may not be productively engaged. Therefore, the administrator role is added to the existing paradigm in this work, and the stakeholders are connected to it. This enhanced connection can yield productive results, as it is closer to the institute's overall functioning.

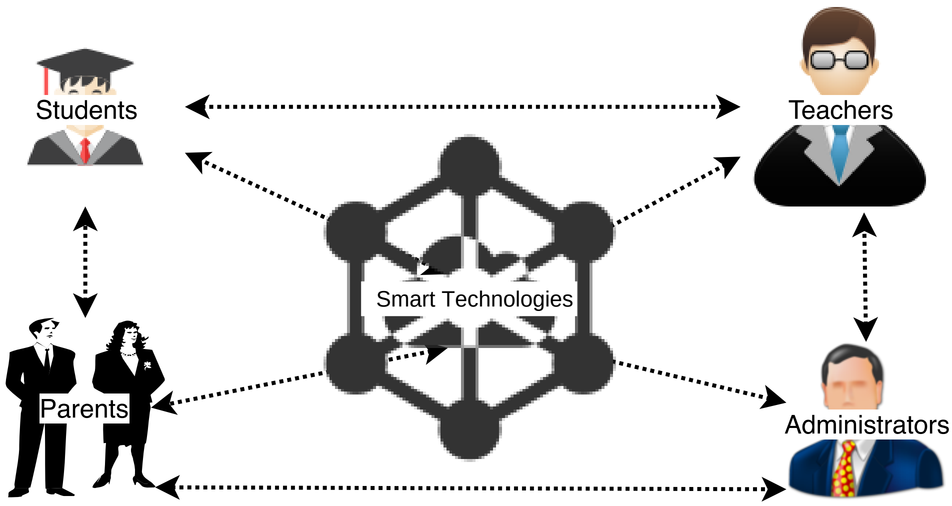

Figure 1. The architecture of the smart institution framework.

Therefore, to address the challenges of the traditional educational system, the contributions of this article are as follows:

1. We propose a five-element framework that includes students, teachers, parents, administrators, and smart devices. These devices digitally connect stakeholders to productively engage learners in the teaching–learning process.
2. Parents play a passive role in the traditional education system. Our proposed model utilizes smart devices and applications to foster strong relationships among learners,

parents, teachers, and administrators. Smart lesson plans, homework, school activities, and other smart reports are shared with parents, administrators, and teachers.

3. The proposed framework assists teachers in actively engaging learners in the classroom and enhances their teaching and assessment skills by saving time with smart attendance and smart reporting. Similarly, it enables administrators to manage the institution efficiently and handle reports transparently. This is a critical step toward making informed decisions.

The rest of the paper is arranged as follows. Section 3 reviews the related literature and projects concerning smart institutions, such as smart administration and smart pedagogy. Section 4 discusses the proposed framework for smart institutions and explains how it works. Section 5 covers the experimental setup, where various experiments have been made to evaluate the performance of the proposed system model. Section 6 discusses the technical and social challenges. Finally, Section 8 concludes the study and outlines directions for future work.

2. Concepts and Terminologies

This study adopts a multidisciplinary approach that incorporates education with information and communication technology (ICT). To facilitate a comprehensive understanding of both fields, this section is divided into two subsections: (i) educational terminology and (ii) smart system terminology. These subsections clarify the essential concepts and terminologies used throughout this article.

2.1. Educational Terminologies

This section introduces key educational terminologies. Pedagogy encompasses various teaching methodologies, including classroom basics and psychological aspects. Lesson Plans provide pre-class blueprints to manage teaching effectively. Assessment evaluates student learning, providing insights for decisions about individuals, teachers, and institutions. Portfolios store records and project-related data, serving as a basis for future decisions and AI training. Engagement denotes students' active involvement in the classroom, encouraging productive learning. The Flipped Classroom inverts traditional teaching, utilizing recorded videos for home learning under teacher supervision. Personalized Learning allows students to select their learning preferences, enhancing engagement. Activities engage students in cognitive and physical tasks, promoting productive learning. Question Banks optimize assessments by storing and auto-populating topic-related questions [25–27].

2.2. Smart System Terminologies

In the ICT, we explore essential terms. Smart signifies intelligent technology applications that are often seen in IoT and artificial intelligence. The Internet of Educational Things includes smart education devices. IoT is a network of interconnected devices integrating embedded technology and AI for smart decision-making. MOOCs offer remote learning through platforms like Coursera and edX. LMS aids educational interactions, while Virtual Classrooms refer to online classes. AI powers smart decision-making. VR and AR provide immersive learning; the 5th Generation ensures real-time communication. MCUs and Fog Computing manage smart sensors, and Cloud Computing offers online resource access through IaaS, SaaS, and PaaS [25,28].

3. Background and Motivation

The COVID-19 pandemic has caused a lot of harm; however, it has also brought about some new trends and changes earlier than expected [29,30]. The prolonged lockdowns transitioned classroom environments to virtual settings, comprising lectures, examinations, activities, assignments, meetings, etc. Microsoft education center applications, i.e., Microsoft teams [31], Flipgrid [32], Forms [33], OneNote [34], Whiteboard [34], Lens, Stream, etc., massively served educational institutions during the COVID-19 pandemic. Along with the learning style, digitization also changed institutional management [9]. Similarly, authors in [35] covered the utilization of IoT in educational institutions. However, this report recommends the use of IoT in educational institutions with intensive care. Several studies recommend using this technology for learning and teaching, especially facilitating disabled learners [36,37]. The subsequent section covers the literature on smart systems for administration and teaching in educational institutions.

3.1. Smart Administration

Smart administration has been studied since 2010, with sensors enabling approaches [38] and the use of AI algorithms to assist in the running of organizations. Several organizations are working on educational leadership tools; however, Microsoft [34] is proposing new tools that integrate with new technologies for educational leadership. Their products, such as Microsoft Teams, are used to manage staff, share directions, and manage virtual meetings. Similarly, Google [39] is providing leading services for the management of educational leadership.

Managing resources in institutions is challenging, particularly when resources are limited. The authors of in [40] used IoT technology to manage classroom furniture according to the strengths of students.

Similarly, the authors in [41] used radio frequency identification (RFID) for a student attendance system. The RFID-embedded cards were issued for experimentation. Attendance was also automatically marked as a student entered the class. The same technologies were used by [42] to protect the students in school.

This concept was further explored by the authors in [43], where they introduced the concept of a flexible classroom that enabled students to easily adjust their seating and orientations, thus facilitating better interaction. The instructor taught Introduction to Electronic Circuits (IEC) for one year in a traditional classroom and the following year in a flexible classroom. They found that the results of the flexible classroom were better than those of the traditional classroom. Extending the same concept, the authors in [44] focused on addressing the under-utilization of classrooms on a college campus to bridge the gap between enrollment and attendance. Various IoT sensors in real-time were used to effectively use classrooms. With the aid of AI (to predict attendance and optimal class allocation), they minimized space wastage.

The smart campus is widely discussed in academia. The authors in [45] extend this concept and investigate the smart university concept. They used IoT to manage the university environment (i.e., parking, lighting, tracking, and inventory, etc.). Smart security is the focus of smart cities and smart campuses. The authors in [5] proposed a smart security framework that uses smart sensors to monitor the institutions' premises. In case of a security breach, the concerned authorities are informed. For monitoring purposes, the authors of [22] provide a comprehensive review of the use of video images, deep learning neural networks, and a new Pleasure, Arousal, and Dominance (PAD) emotion model to assess student concentration in online classrooms. The authors used the DAiSEE dataset, a new sampling script, and a neural network to test the accuracy of the system. The authors have thoroughly explored the potential of deep learning and PAD emotion models in assessing student concentration, and the results of the study are promising. Similarly, the authors in [46] have used IoT to reduce educational costs and maximize performance.

3.2. Smart Pedagogy

Students' learning styles are just like fingerprints, everyone has a different style of learning [7]. If there are 30 students in the class, this means that 30 different philosophies are set. Filling this diversity is not easy, which leads to dropout or poor engagement. With the integration of technology with education, it is possible to address all these challenges. Leading organizations are working on educational technologies; however, Microsoft [34] has introduced several tools for educators to digitize teaching and learning. They introduced Microsoft Teams, Flip Grid, Forms, Assignments, etc., which are tools used to digitize the teaching–learning environment. Similarly, Google Teacher Center [39] provides numerous education services such as Google Classrooms, Meet, Assignment, Forms, etc.

To address the learning challenges, the authors in [47] proposed an artificial intelligence framework that suggests teaching and learning styles. This framework includes various teaching styles, and when learner data is entered, it suggests the most appropriate style. Furthermore, flipped classrooms have become a leading trend in education, especially during the COVID-19 pandemic, and are being utilized by numerous organizations. In [48], the authors explored the concept of the flipped classroom, where classes are delivered online using smart devices to facilitate lesson activities. Instead of physical classes, students attended classes online using the learning management system (LMS) from their homes. All classroom-related activities were conducted to maintain engagement, similar to how they would occur in physical classrooms.

Co-education is not preferred in many regions, customs, and religions. In this social context, the authors in [49] have explored this issue and proposed a framework in which a male teacher educates both male and female students attending classes virtually via laptops, tablets, or mobile phones. Additionally, the insights presented by the authors in [50] delved deeper into the virtual learning environment and highlighted the significance of IoT devices. They harnessed the power of fog and cloud computing layers to process the copious amounts of data generated by various devices within virtual learning. In a separate endeavor, the authors in [51] introduced a bidirectional digital teaching approach, wherein students used their computers and tablets to access learning resources. A significant challenge in virtual classrooms is the limitation of teachers' ability to effectively guide students. Moreover, students have diverse learning preferences, which are not readily accommodated by the virtual classroom [52].

4. System Model

The adoption of smart technology enables innovative solutions to improve the learning process. The proposed work is divided into two sub-layers. The first is the technical layer, which discusses how technical the proposed work is implemented, and the second is the human resources layer, which discusses all stakeholders involved in the teaching–learning process. This section discusses the implementation and functioning of these layers. Table 2 shows the symbols and notations used in this study.

Table 2. Symbols and notations used in this article.

Symbol	Definition
$RFID$	Radio frequency identification
χ_{std}	Student attendance
$SFID$	Sound frequency identification
$admin$	Administrator
rst	Results
std	Student
τ	Threshold values
α_{att}	Attendance notification
α_{Env}	Environment notification
SR	Smart result
TPR	Teacher progress report
χ_t	Teacher attendance
$\alpha_{streaming}$	Video live streaming
$\alpha_{Streaming}$	Camera live streaming
$\alpha_{reports}$	Reports notification
T	Teacher
μ	Smart board
per	Parent
α_{Noise}	Noise notification
SPR	Smart progress report

4.1. Technical Layer

The technical layer comprises different types of smart devices, servers, and applications [53] (as shown in Figure 2). Technically, this layer is further divided into IoT, fog, and cloud layers. The IoT layer has smart devices, which read and send the required data to the local fog servers [54]. The local server analyses the data and sends or receives data from the cloud servers according to the need.

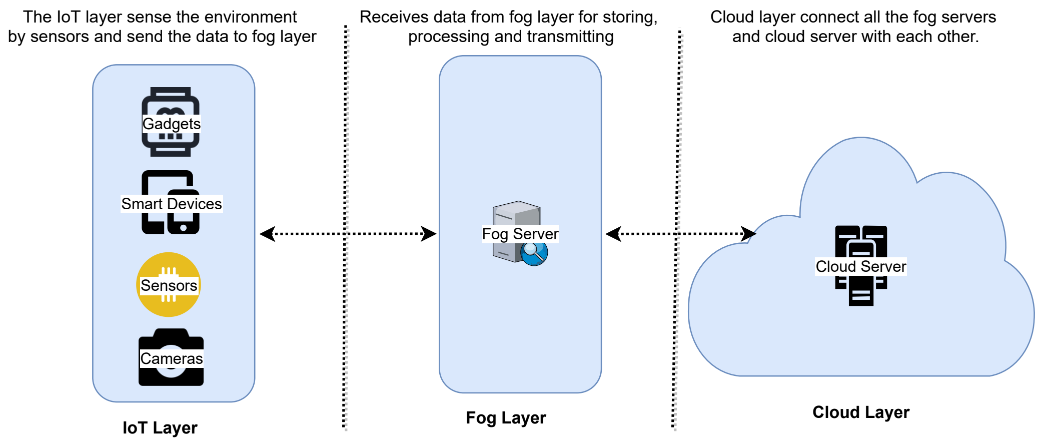

Figure 2. Structure of the technical layers in the SIF.

4.1.1. IoT Layer

In the IoT layer, a variety of smart devices and sensors are employed to transmit data to servers operating within the fog layer. These devices (e.g., sensors, cameras, smart boards, tablets, laptops, and more) are typically installed in institutions. They can operate automatically or be controlled by users such as students, teachers, administrators, or parents. This section provides a detailed exploration of these devices and sensors.

(a) Radio frequency identification: The RFID automatically identifies objects by frequencies attached to them. RFID technology enables automatic attendance tracking for students and staff in institutions. Smart cards with RFID tags are issued to them and RFID readers are installed at the class entrance. As individuals enter, the system records their entry times in the database. This eliminates the need for roll call, which can waste valuable class time. Moreover, accurate timing reports encourage teachers and students to be punctual for their classes, which is often lacking in underdeveloped countries.

$$\alpha_{att}(x) = \begin{cases} Present & \text{if } F_{ID} == std_{ID} \\ Absent & \text{if } F_{ID} \neq std_{ID} \\ Nil & \text{Otherwise} \end{cases} \tag{1}$$

The $\alpha_{att}(x)$ data are updated on fog and cloud servers. This alert message is also forwarded to the guardians of the learners.

(b) Smart Board: Learners forget what they listen to, they retain more by doing and watching. Interactive smart boards aid in learning. Animated presentations and teaching methods are becoming increasingly popular for clarifying concepts. Instead of passively listening to theoretical lectures, students actively participate in practical activities that enhance their understanding. The smart board is a central feature of modern classrooms. It employs contemporary teaching methodologies to keep students engaged. Teachers can display their own material or access resources from the cloud or the internet. Interactive boards are user-friendly, and anyone can operate them. Game-based activities can be seamlessly integrated to teach and stimulate students' interest in learning.

(c) Smartphones: The internet is expected to host a large number of devices in the near future. Smartphones are widely accessible, even in low-income regions, and can serve as powerful learning tools for educators, learners, and parents. One of the emerging pedagogical approaches that relies on smartphones is the flipped classroom, which has gained popularity in recent years.

$$\alpha_{reports}(x) = \begin{cases} Homework & \text{if Updated} \\ Attendance & \text{if Updated} \\ Assessments & \text{if Updated} \\ P_{Report} & \text{if Updated} \\ Meetings & \text{if Updated} \\ Nil & \text{Otherwise} \end{cases} \tag{2}$$

(d) Smart Sensors: Different types of smart sensors are installed in institutions. These sensors continuously monitor and capture data from various parameters within the institutions in real time.

$$\alpha_{Env}(x) = \begin{cases} Temp & \text{if Requested} \\ Humidity & \text{if Requested} \\ Air & \text{if Requested} \\ Sounds & \text{if Requested} \\ Vibrator & \text{if Requested} \\ Nil & \text{Otherwise} \end{cases} \tag{3}$$

(e) Smart Cameras: Institutions and classrooms use cameras to track and record their activities, which are transmitted to the fog layer in real time. Cameras enhance the safety and accountability of institutions. AI applications can analyze the learners' behavior from the camera data.

$$\alpha_{Streaming}(x) = \begin{cases} FogServer & \text{Round the clock} \\ CloudServer & \text{if Requested} \\ Parents & \text{if Permitted} \end{cases} \tag{4}$$

(f) Sound frequency identification: Classrooms are equipped with sound frequency identification (SFID), which measures the sound intensity in the rooms. If the sound intensity exceeds a predefined threshold, a message is sent to the principal's office.

$$\alpha_{Noise}(x) = \begin{cases} FogServer & \text{Every-time} \\ PrincipalOffice & \text{if Crossing Limit} \\ Cloud & \text{if Permitted} \end{cases} \tag{5}$$

(g) Smart speaker: Instead of using the traditional bail and caller system, smart speakers should be installed in the institution. This automatically informs students and teachers regarding classes and other important messages.

(h) Biometric system: Biometric verification is used for individual human verification. We used biometric devices for employee attendance. This makes employee attendance more transparent than the RFID system [55].

4.1.2. Fog Layer

All data coming from the IoT layer are stored and processed on fog layer servers. One of the objectives of fog computing is to reduce the network burden. Smart devices generate and transmit large amounts of data for intelligent analysis and action.

(a) Local servers: Servers are situated within the institutions, and they serve as hubs to which all the devices in the IoT layer are connected. These servers both store and process all incoming data, and when necessary, they transmit it to the subsequent cloud servers.

(b) Smart reporting: The local server receives data from all smart devices and sensors connected to IoT layers. The data and streaming are stored in the database. Institutional administration and parents can view institutional and student reports on their registered devices, which are connected to fog servers. The server's algorithms also notify principals or parents when certain conditions are met. These reports may include smart results, students' progress reports, teacher progress reports, etc.

$$\alpha_{SR}(x) = \begin{cases} Not(rslt) & \text{if result is updated} \\ Not(meeting) & \text{if Updated} \\ Nill & \text{not above} \end{cases} \quad (6)$$

$$\alpha_{SPR}(x) = \begin{cases} Not(Monthly) & \text{if 1st of the month} \\ Not(Weakly) & \text{if Last day of the weak} \\ Nill & \text{not above} \end{cases} \quad (7)$$

$$\alpha_{TPR}(x) = \begin{cases} Not(Monthly) & \text{if 1st of the month} \\ Not(Weakly) & \text{if Last day of the weak} \\ Nill & \text{not above} \end{cases} \quad (8)$$

where $\alpha_{SR}(x)$ denotes the results notification, $\alpha_{SPR}(x)$ denotes the notification for the performance reports of students, and $\alpha_{TPR}(x)$ denotes the teacher performance notification.

(c) Flipped classrooms: Fog computing supports the implementation of flipped learning, an innovative pedagogical approach that reverses the traditional roles of homework and classroom instructions. In flipped learning, teachers create video lessons that students can access at home, while classroom time is devoted to engaging in active learning tasks with the teacher's guidance. The fog server hosts and distributes the video content and assignments, enabling parents to monitor the progress of students through their smartphones [56].

(d) Assessment: To ensure the fair and accurate evaluation of teachers and students, assessment transparency is essential. Smart testing services enable the examination of students and the storage of their results on fog servers. These records facilitate transparent reporting and decision-making.

4.1.3. Cloud Layer

The cloud layer enables higher authorities to access comprehensive data from registered institutions. This layer employs intelligent algorithms to allow top authorities to effectively oversee all the institutions. The cloud layer includes cloud servers and educational applications.

(a) Cloud server: Education systems are interconnected by a network of fog servers and other specialized servers. This network enables the exchange of institutional data, records, videos, and other resources among the systems.

(b) Educational applications: These applications run policies and formulas to efficiently manage the resources.

4.2. Human Layer

This layer addresses the stakeholders who play a role in the teaching–learning process. Educational scholars [7] proposed a learning structure of three elements: students, teachers, and parents. In today's modern world, where schools are run in an organized way, administrators must be included. The learning–administration process revolves around administrators. Teachers, parents, and students cannot make any decisions without administrators. Therefore, we have integrated the administrator into the heart of the traditional teaching–learning model. The existing educational frameworks discuss learners, parents, and teachers; however, administrators are usually not included. We proposed a new paradigm to add administration to the existing framework, as shown in Figure 3.

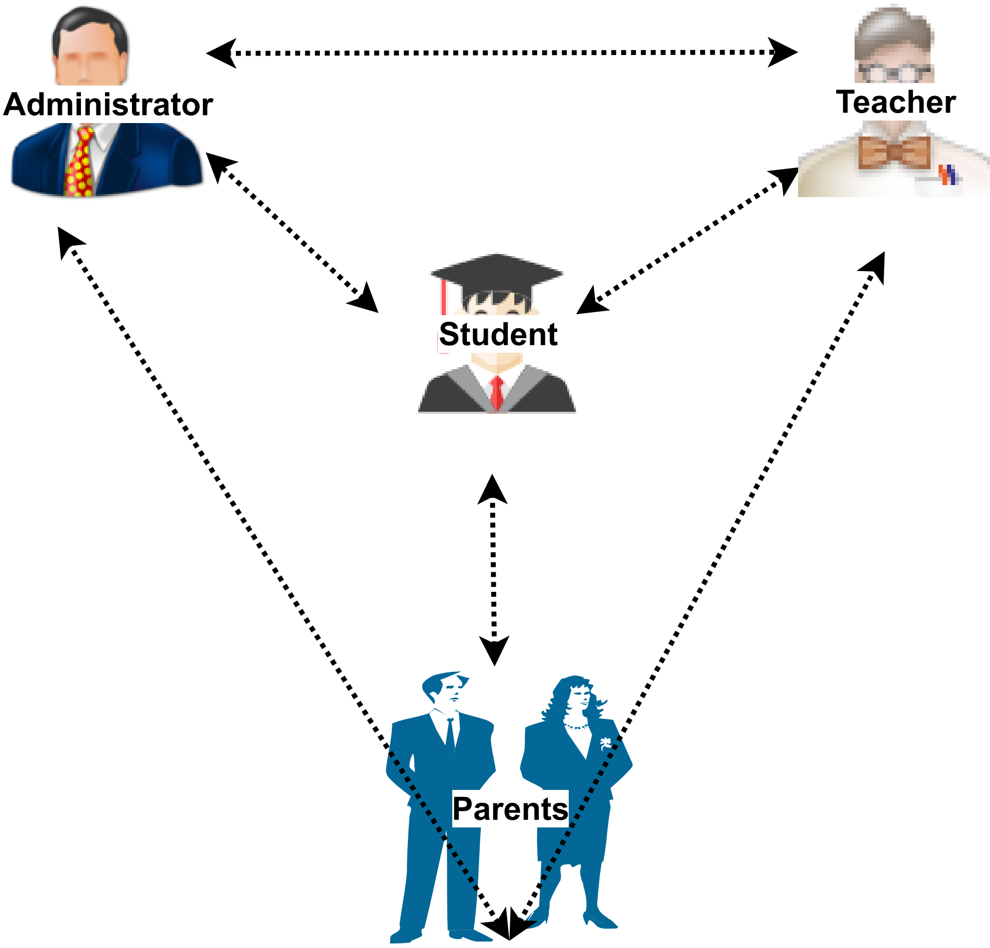

Figure 3. The human layer structure of SIF.

4.2.1. Learners

One of the core entities of educational institutes is learners. Today's students are the future leaders who will shape our society. If we instill in them the values of being good humans today, they will undoubtedly contribute to building a better society tomorrow.

4.2.2. Teachers

It is widely acknowledged that the quality of a country's education system relies heavily on its teachers, who are considered the central element of the learning process. Teachers utilize smartphones, computers, and cameras to transmit data to the fog layer. They employ smart technology to enhance their teaching methods, making their classes more captivating, engaging and, ultimately, more effective.

4.2.3. Administrators

Based on the data and reports from the IoT layer, administrators formulate policies and strategies that affect the performance of institutions or the entire education system. Their role is crucial as they shape the direction and outcomes of education. Therefore, it is crucial to show transparent reports on their interfaces. Understanding transparency, this framework reports accurate data to top administrators.

4.2.4. Parents

Parents in low-income countries often face barriers to engaging with their children's education. They may struggle to afford school fees, materials, or transportation, or they may lack the time, skills, or confidence to support their children's learning at home. However, parental involvement is crucial for enhancing the quality and effectiveness of education. When parents are actively involved, children tend to be more motivated, confident, and successful in their studies. The fog layer assists parents in staying informed and connected with their children's educational journey. It updates them automatically about their children's progress, achievements, and challenges, and provides feedback and guidance on how to better support their children's learning.

4.3. Model Performance

This section discusses the detailed performance of the proposed model. Front-line smart devices and sensors collect data from the environment and forward them to the fog layer's servers. The fog layer analyzes the data by the algorithm and makes decisions. If required, the data are streamed to the cloud server.

4.3.1. Smart Attendance

Manual attendance consumes time and is one of the most boring activities considered. The current school schedule, with 8 periods of 40 min and at least 60 students per class, does not allow manual attendance tracking. The RFID smart card system automates this process by registering the presence and timing of students and teachers as they enter the classroom. The system also informs the teacher and principal about the number of students in each class. The technology operates seamlessly and quietly. The RFID smart card system also notifies parents when their children arrive or depart from school, enhancing their awareness and safety. Additionally, the system records student activity when they access the library, cafe, labs, etc.

4.3.2. Smart Reporting

In institutions, monitoring teachers' and learners' progress is necessary. An important part of operating an institution is to keep track of the overall teacher performance. With the proper evaluation of teachers, an institution can improve significantly as well. Learners' assessments, attendance, and character records are stored in databases. The application informs parents about the new complaints. The summary of learners is accessible to teachers or parents. This enables parents and teachers to identify the problems. The school administrator can monitor the school activities in real time. They can review any teacher's lesson plans, homework, courses covered, and results. Parents can also see the homework and lesson plans directly to facilitate the flipped classroom environment.

4.3.3. Smart Pedagogy

Flipped classrooms are the best option, but in a developing country, it is not possible to implement them in full spirit. We should integrate traditional and flipped classrooms to maximize learner engagement in underdeveloped countries. It is not possible in developing countries and in public schools to implement flipped classrooms fully; however, they may be integrated to obtain the benefits of flipped classrooms. This connection engages parents and enhances teachers' professional development.

4.3.4. Smart Lesson Planning

Lesson planning is a crucial task that requires smart and transparent execution. It helps to ensure that the teacher is following the standard operating procedures and addressing the learning objectives. The lesson plans of each teacher and class are accessible to the principals, learners, and parents for feedback and evaluation. The system automatically detects and reports any low performance or deviation from the lesson planning guidelines. Teachers can use previous or hired lesson plans as a time-saving strategy. Microsoft developed a smart application, denoted as "sway", to prepare the lesson plan in 5 min and share it with anyone [57].

4.3.5. Student Engagement

Learners' motivation and engagement are crucial for the learning process. Student engagement increases the critical thinking of the students. In traditional classes, it is observed that a minimum number of students are engaged. To maximize the quality of education, we must increase learner engagement.

4.3.6. Smart Assessment

Assessments measure the performance of teachers, students, and the syllabus. Good and fair assessments can guide institutions in the right direction. Information & Communication Technology (ICT) tools are used to conduct these assessments and to store their results in an online database. These results are then used to check the performance of teachers and students.

4.3.7. Smart Administration

The administration's decision depends on the data put on their tables. If fair data are reported, fair decisions are made. Smart technology assists in automatically and smartly managing organizations. Smart technology helps in smart evaluation, smart reports, smart performance evaluation reports (PERs), smart leave, smart meetings, smart monitoring, etc.

5. Performance Evaluation

This section covers the experimental setup and results evaluation. The results evaluation is categorized into two sections. The first section covers the technical performance and the second section covers the system's effects on learners. Figure 4 shows the experimental setup for SIF.

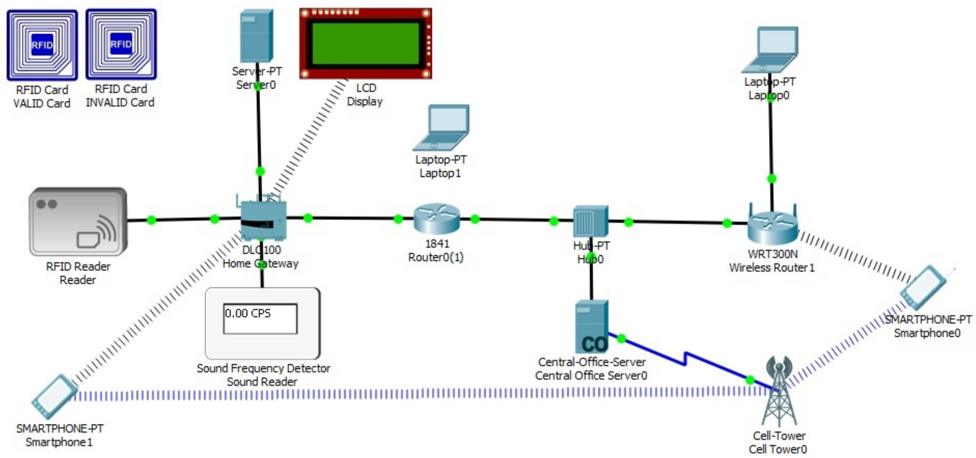

Figure 4. Experimental setup for SIF evaluation.

5.1. Technical Performance

To measure the technical performance, we developed a prototype to experimentally observe the system's performance. The following devices were used for the experimental setup.

In the simulation environment, RFID readers with two cards were placed. The reader was connected to the device layer. In the fog layer, the readings were displayed on a display screen. When an RFID card is brought closer to the reader, it is read and attendance is sent to the server. The simulation result shows that it takes 2 ms to communicate the RFID reading with the liquid crystal display (LCD) placed on the fog layer. The results are shown in Table 3.

Table 3. Evaluating the performance of the RFID system.

Type of Test	Checking the Performance of the RFID System
Source Device	RFID Reader and Card
Target Device	Server and LCD
Expected results	Updating database
Status	Successful
Response time	0.01 ms
Avg execution time	2.00 ms

The SFID is used to read the intensity of sounds. It reads the environment sounds and displays the results on the server. Limits are applied to sound intensity; when the noise increases to a certain level, the head office is notified. The experimental result shows that it took 2.19 ms to communicate the SFID reading to the fog layer. The results are shown in Table 4.

Table 4. Checking the performance of the SFD system.

Type of Test	Checking the Performance of the SFD System
Source Device	Sound frequency detector
Target Device	Server and LCD
Expected results	Sending notification
Status	Successful
Response time	0.01 ms
Avg execution time	2.19 ms

When a child enters the school, RFID detects the ID, and a message is sent to the parents, such as "Your child safely reached school". When the same student leaves the school gate, a message is sent to the parents, such as "Your child has left for home". The experimental results show that the cellular network took 500 ms to deliver the message to the parent's device. The results are shown in Table 5.

Table 5. Delivery of the message on the cellular network.

Type of Test	Delivery of Message on Cellular Network
Source Device	RFID Reader and Card
Target Device	Mobile phone
Expected results	Delivery of message
Status	Successful
Response time	0.01 ms
Avg execution time	500 ms

As discussed in the methodology, the proposed framework runs on three technical layers. This experimentation discusses the transfer of data from the IoT device layer to the fog layer. The results show that data are successfully transferred to the cloud. It took 3 ms to deliver the smartphone's communication to the fog layer. The results are shown in Table 6. Similarly, Table 6 shows the data updating on cloud servers.

Table 6. Updating of data on the fog servers.

Type of Test	Updating of Data on the Fog Servers
Source Device	Smartphone
Target Device	Fog Server
Expected results	Success in full data updating
Status	Success
Response time	0.01 ms
Avg execution time	3 ms

Similar to the fog layer, this experiment examines the transmission of data from the IoT devices to the cloud layer. The outcome indicates that the data transfer to the cloud was successful. Smartphone communication reached the cloud layer in 500 ms. The outcomes are displayed in Table 7.

Table 7. Updating of data on the cloud servers.

Type of Test	Updating of Data on the Cloud Servers
Source Device	Smartphone
Target Device	Fog Server
Expected results	Success in full data updating
Status	Success
Response time	0.01 ms
Avg execution time	500 ms

Table 8 shows the protocols used by devices during transmission. To measure the latency of the data transmission, we employed the ping command. The camera used internet control management protocol (ICMP); the laptop used ICMP and address resolution protocol (ARP); the servers used IoT, ICMP, and spanning tree protocol (STP); the smart board used IoT, ICMP, and STP, and the cellular networks used IoT, ICMP, and STP.

Table 8. Protocols used in the simulation.

Devices	Protocols Used in the Simulation
Camera	ICMP
Laptop	ICMP, ARP
Server	IoT, ICMP, STP
Smart-board	IoT, ICMP, STP
Cellular Network	IoT, ICMP, STP

5.2. Performance in Terms of Learner Engagement

To check the productivity of the current framework in the institution, the Government Girls Secondary School in Trag, Punjab, Pakistan, was selected to carry out a case study with the learners. We assessed the framework to determine whether it enhances the quality of learning. In the initial stage, we registered teachers and parents with the system to enable automatic communication. Every month, automatic reports were sent to the parents, and the system's performance was evaluated every month in parent–teacher meetings.

As we can observe in Figure 5, students connected to the smart system experienced a significant increase in the number completing their homework, rising from 100 to 499 students. Similarly, student complaints have also decreased, possibly because the system informs their parents about each complaint.

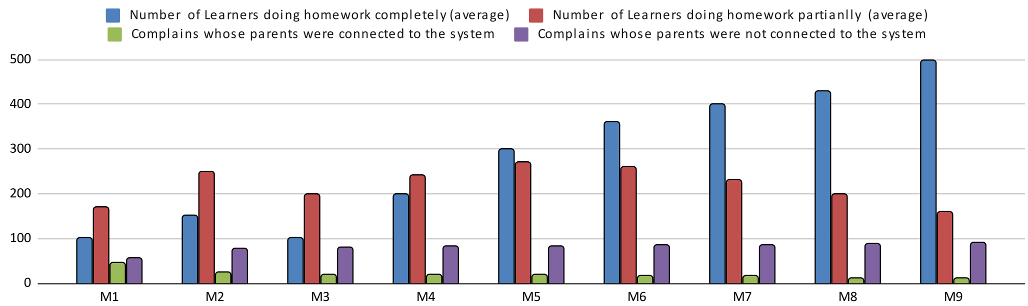

Figure 5. Student engagement for the academic year 2019–2020.

Additionally (as shown in Figure 6), the pass rates for the academic years 2018–2019 and 2019–2020 are as follows: For the academic year 2018–2019, the monthly progress reports of learners with more than 40% marks were 28%, 30%, 28%, 35%, 43%, 55%, 66%, 72%, and 72%, respectively. For the academic year 2019–2020, the rates were 18%, 23%, 20%, 30%, 35%, 47%, 50%, 60%, and 63%, respectively. The academic year 2019–2020, which involved active communication between parents and children through the system, demonstrated great success.

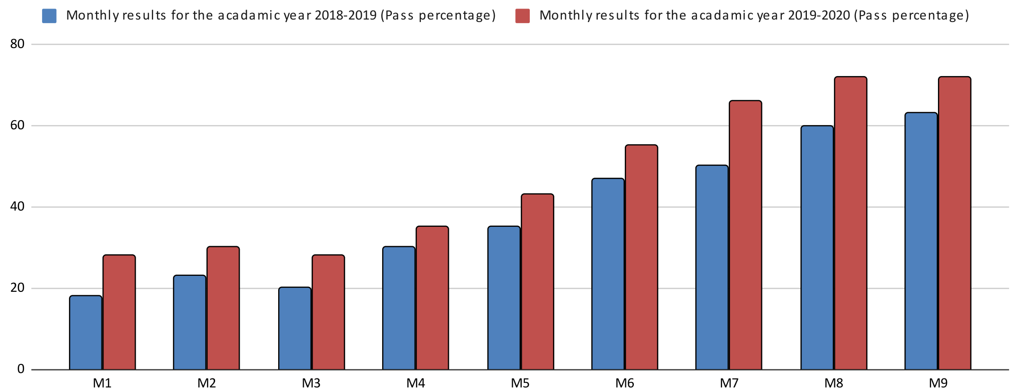

Figure 6. Comparison of learner outcomes for the academic year 2019–2020 between (i) those who were connected to the system and (ii) those who were not connected to the system.

The productivity of students whose parents received system notifications about their attendance and homework was higher than that of those whose parents did not receive such notifications, as shown in Figure 7. The parents who were notified by the system about their children saw attendance increase to 50%, 58%, 50%, 60%, 60%, 64%, 67%, 70%, and 70%, respectively, while the learners whose parents were not connected to the system were at 22%, 25%, 20%, 30%, 30%, 26%, 29%, 28%, and 28%, respectively. Furthermore, the homework progress of students whose parents were connected to the system is 25%, 40%, 33%, 45%, 58%, 66%, 69%, 69%, and 69%, respectively, and similarly, those who were not connected to the system are at 15%, 18%, 11%, 15%, 20%, 21%, 21%, 21%, and 22%, respectively.

At the end of the year, 90% of the complaints were registered in the complaint register (as shown in Figure 7); this belonged to the learners whose parents were not connected to the system or who did not cooperate in parent–teacher meetings.

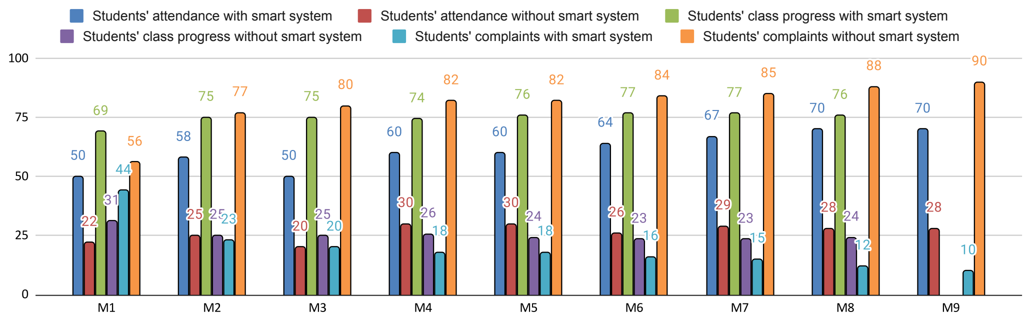

Figure 7. Comparison of learner engagement for the academic year 2019–2020; those (i) who were connected to the system and (ii) those who were not connected to the system.

6. Challenges

A smart system has many advantages; however, there are also many obstacles to its deployment. There are two primary types of obstacles to its deployment: (i) technical challenges and (ii) social challenges and resistance [8].

6.1. Computational Challenges

Computational challenges arise during smart system installation and integration. Common issues include network, battery, or communication failures, and malfunctioning built-in features requiring expert intervention. Additionally, updating the code can be user-unfriendly. Specific challenges in smart education include:

- Installation and Integration: Involves complex algorithms and software configurations.
- Network, Battery, and Communication Issues: Frequent disruptions in the network, battery, and communication affect device performance.
- Malfunctioning Built-in Features: Core feature failures necessitate expert intervention.
- Code Updating: Users may face challenges in updating program changes.
- Internet Connectivity: Requires reliable internet access, limiting deployment in areas with poor connectivity.
- Privacy Issues: Sharing personal data can lead to privacy breaches, requiring robust data protection measures.
- Compatibility and Interoperability: Ensuring different devices and platforms work seamlessly is a complex task.
- Data Pollution: Managing excessive and irrelevant data is essential to maintain data quality.
- Artificial Intelligence: Implementing AI can be expensive and is still an emerging technology, which raises issues of trust.

6.2. Social Challenges

Despite numerous benefits, smart systems encounter various social challenges. A major issue is the adoption of modern technologies, especially among those lacking sufficient information to use these systems. Specific social challenges include:

- Lack of Technical Knowledge: Users, especially in underdeveloped regions, may lack the technical knowledge needed to use smart systems.
- Employee Resistance: Resistance from employees, such as teachers who are uncomfortable with real-time monitoring, can be a challenge.
- Use of Smart Systems: Teachers' lack of familiarity with smart devices may hinder system implementation.
- Lack of Funds: Limited budgets in underdeveloped areas can hinder the adoption of smart systems.
- Cultural Issues: Cultural norms, such as privacy concerns for girls, can affect the acceptance of smart systems.

- Technology Addiction: Students' addiction to mobile devices and applications can divert their attention from learning.
- Digitizing Books: The cost and effort required to digitize educational material and create animations for AR and VR can be substantial.
- Training: Training teachers for smart systems can be costly, time-consuming, and may not always lead to the desired level of expertise.

7. Comparative Analysis

In this section, we provide a comparative analysis of our study in relation to prior research. Our approach introduces a five-pillar framework designed to enhance student engagement in educational institutions, fostering productive collaboration between students, parents, and teachers. Within this framework, smart emerging technologies, such as IoT, AI, and 5G play a crucial role.

When examining previous studies, we observed a prevailing trend where the authors primarily focused on the technical aspects while neglecting the equally essential pedagogical perspective, a fundamental element of educational institutions. For instance, in [58], the authors employed sensors to monitor health and education. Similarly, [53] explored the utilization of smart education within smart cities. Meanwhile, [59] delved into the application of the Internet of Things (IoT) in higher education, with a specific focus on COVID-19 implications.

Conversely, several extensive studies concentrate on single functionalities of smart education. For example, [60] explores the use of smart boards in the classroom, while [61] investigates neural networks in education to facilitate smart decision-making for quality education. Additionally, [62] explores the integration of digital education into traditional educational settings.

Furthermore, other studies, such as [38,43,47,50,53,56,63,64], discuss the integration of smart systems into education. However, these studies tend to focus on one aspect of smart education while overlooking the rest. Moreover, they often neglect the crucial role of pedagogical and learning theories in the teaching–learning process. This limitation creates a potential trust gap. In contrast, our framework is firmly grounded in traditional teaching and learning theories, effectively bridging the gap between conventional education and smart education, enhancing its reliability and applicability.

8. Conclusions and Future Directions

In summary, this article addresses significant challenges within educational institutions, particularly in schools in developing countries, where standard operating procedures (SOPs) are often not adhered to, and students are not fully engaged in productive learning. Smart computing technologies turned traditional institution activities into smart activities, such as smart attendance, smart monitoring, smart reporting, smart lesson planning, smart pedagogy, smart student engagement, self-directed learning, a flipped classroom, smart assessments, smart security, etc. These smart technologies have introduced a transparent monitoring and analysis system, thereby strengthening the relationships among parents, teachers, students, and principals, leading to heightened student engagement and learning outcomes. Overall, the results of this smart institution framework (SIF) are promising, as it enhances the engagement of learners, parents, and teachers.

Looking ahead, our plan involves extending this work to higher education institutes, as one of the challenges is dealing with more complex data analysis and reporting tasks. We aim to examine how advanced analytics and reporting tools can be integrated into the educational process, allowing educators and administrators to obtain more refined and comprehensive views of student performance and engagement.

Author Contributions: This work was carried out in collaboration among all authors. A.B., G.U.R. and A.G. designed the detailed methodology. S.S. and M.M.N. managed the literature searches and analyses. M.Z. and H.F. wrote the first draft of the manuscript. The final draft of the paper was completed by A.B. and G.U.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Acknowledgments: The authors would like to thank Prince Sultan University and the Smart Systems Engineering Lab for their support.

Conflicts of Interest: The authors declare no conflict of interest.

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