

IoT: A study into the effectiveness of smart classrooms

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Abstract — Smart technologies are now commonplace across a variety of different sectors from agricultural, to healthcare and the education sector, we have seen a technological revolution happen regarding smart wearable devices, more and more people are turning to wearable devices to monitor their physical health and physiology. There are several technologies in the education sector, specifically in classrooms that aim to improve the immersion and interactivity of learning material, but they don't come without their challenges which prevent implementation for several institutions due to a plethora of issues. This paper studies the components of smart classrooms, discussing their merits and challenges with an aim to gauge their effectiveness at achieving their intended outcomes, IoT technologies are highlighted and discussed as they form a fundamental backbone to smart classroom architecture with the future of both IoT and smart classrooms being covered. The paper then concludes with a summary of the material covered.

Keywords—IoT, internet of things, smart classroom, education, technology

I. INTRODUCTION

The technological world today has never seen a revolution like the one the internet of things (IoT) has begun, with over 20.4 billion devices connected to the internet the impact of IoT is colossal it has transformed the world across multiple sectors ranging from agricultural to healthcare to the education sector. Spearheading the fourth technological revolution, IoT is defined by the Oxford dictionary as “the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data”. The enhanced levels of data connectivity have led to a paramount level of heightened communication allowing for huge practical benefits. The IoT encompasses many embedded devices from mobile phones, tablets, wearable devices such as smart bands, RFID to any other smart device with data connectivity.

These interconnected objects communicate with each other allowing them to control and manipulate the environment they are in, they do however differ from traditional technologies as they involve a large number of different devices with complicated hardware and software components, they lack easy classification and identification, and with a lack of standardization plaguing the IoT landscape, this problem is becoming more and more prevalent as things develop [1].

Today the IoT is broadly spread across a number of different domains offering huge advantages to those whom choose to

adopt its technologies, technology in education is not a new concept and has been around for a number of decades, we have seen evolving teaching methods from the traditional black board and chalk technique to powerpoint presentations and interactive whiteboard use, the IoT is not an exception to this rule and has helped the educational sector catapult its way into the future at a rapid rate. Technology such as RFID readers installed at schoolgate entrances, libraries, café's and teaching buildings can be implemented to help educational facilities in a lucrative way. Utilizing IoT, teaching staff can manage teaching sessions in smart classrooms with gestures or voice and facial recognition and communicate with remote students at different geographical locations with relative ease. They can also collect feedback from students regarding interests and likeability of a teaching session, automatically collect data from sensors and process analytics regarding student behaviour, interest, performance and participation [2]. From the students perspective IoT can aid in the communication between classmates both local and remote discuss and annotate learning materials and can help access remote learning resources additionally it can provide students adapted learning resources throughby integrating context (based on time, student interaction, knowledge level and more) [2]. From the staffs perspective IoT finds itself monitoring student emotional states and the classroom environments they work in, in other terms maintaining students psychological health, other uses involve the monitoring of noise amongst classrooms and automatically sending out a warning if a classrooms noise exceeds a certain level.

Equipment can be tagged, tracked and monitored using RFID, collected data can be analysed to find trends and inefficiencies. IoT can also assist staff in managing events such as registration and sports events with regards to managing safety and security, through the use of smart meters it can help monitor and manage institutions energy usage [2]. The uses and applications of IoT are vast and expansive and the previous listings are not exhaustive, this study focuses on the particular applications of IoT within smart classrooms and its effectiveness at facilitating improved learning and enhancing of quality of life.

II. CURRENT TECHNOLOGY

Aside from IoT, educational institutions employ several different technologies to aid with the learning experience, things have come a long way since the black board and chalk days, with interactive whiteboards and digital presentations replacing said methods. It has been shown that

the inclusivity of modern equipment and technology allows students to find the learning experience more interactive as well as more interesting and increases learning as a whole [3]. The transfer of knowledge therefore becomes much more convenient allowing for an enhanced learning experience.

A. Internet connections and round the clock connectivity

The introduction of the internet allowed for a huge increase in information transfer and networking capacity. Educational institutions employ the internet to allow for the use and access of informational material stored online and educational papers and tutorials, it also allows for remote meetings and teaching sessions which would otherwise be impossible to conduct, an element that proved vital during the COVID-19 outbreak of this decade.

B. Projectors and visuals

The use of projectors and other visuals enabled using technology is a popular method of material delivery by teachers and lecturers alike, this technology has found its way into every level of the educational sector and proves invaluable to both its users and recipients. Using digital presentations and projections allows the learning process to stay interesting and increase student motivation [3], the use of visuals is stimulating to students' minds enticing them to think more about their work [3].

C. Online degrees and learning

The internet has facilitated online learning and even allowed for education at degree level to take place entirely by remote fashion, it allows for online learning and study for certifications and other educational awards [3]. Online VLE's exist for educational institutions to take advantage of, centralizing all learning material in one location for students to access with a click of a button on an internet connected device.

D. Networking and remote meeting tools

Enhanced networking through technology has allowed for the use of online meeting tools such as Skype, Microsoft Zoom and more team based environments such as Microsoft Teams, such intercommunication proves vital for staff members in conducting their day to day activities, such technology was highly valued during the 2019 COVID lockdown and was essential in teaching course material which was otherwise unable to be taught in person. Recording technology available allows students to make a record of meetings and material taught in order to reference to re-read at a later point, an invaluable tool from a learner's perspective.

E. Biometric technologies

The use of biometric scanners is common in institutions to ensure access control and attendance confirmations on door and even in the distribution and allocation of school dinners, technology such as fingerprint scanners are employed alongside retina scanners, providing a secure method of student identification otherwise impossible to achieve without the use of technology.

III. APPLICATIONS OF IOT IN SMART CLASSROOMS

As the 21st century heads into the fourth digital revolution IoT is more commonly being seen in the education sector, smart classrooms are choosing to adopt its technologies for

several reasons, this chapter focuses on the different applications of IoT within smart classrooms.

Smart classrooms are the source of smart learning, a type of learning superior to that of traditional learning due to its enhanced levels of interactivity and immersion, such improvements allow for students to understand and properly digest information being transferred to them at a better rate, there are countless opportunities for smart technologies to aid the learning experiences of students through the better understanding of complex topics [4].

Smart classrooms mix both the best practice in traditional methods of teaching as well as distance learning techniques using digital technologies, it is a service-based platform enabling students and teachers alike to interact virtually through different applications. Smart classrooms also make use of technical resources, software and simulators that help quicken the learning process [4].

A. Data technologies

1) Quick Response Codes

Quick response codes are used in smart classrooms to allow to easy and quick access to learning material via a scanner, they are accessed with the use of a mobile device either on android or IOS. This fastened access to learning material helps enhance the transfer of knowledge and allows a higher level of interaction with learning material they establish a connection between the cyberspace and digital world. Offering quick and easy access to digital materials, QR codes are essential in any smart learning environment [4].

2) Smart, wearable devices

Smart devices have become more popular in recent times, especially the use of smart watches, smart devices could be more appropriately defined as 'wearable internet connected computers' which display intelligent information in a readable fashion. In education, smart devices can be used to transfer valuable learner feedback to students without directly disturbing them, streamlining the learning experience, they collect physiological data on persons which can be stored and analysed by computers.

Huge amounts of data is collected and analysed in real time allowing teachers to make informed decisions as to the learning of their students allowing them to better direct materials and tailor learning techniques [1]. It has been suggested that data collected on students with the use of wearable devices could aid learners regarding time management and strategies for learning. Such data can also be used to inform teachers around the best time to timetable activities for students depending on their physiological states and motivation levels. This data also allows for accurate profiling on students which in turn could be used to assess the best groupings for teaching from a teacher's perspective [1].

3) Learner Analytics

Learning analytics is concerning the analysis and collection of learner data for instructing purposes [1]. Leaning towards to most significant benefit that IoT has to offer smart classrooms and learning environments learning analytics is an invaluable asset to any smart classroom's arsenal, it can be used to plan instruction collect data about learners' involvement in lesson and from a teacher's perspective

monitor learner engagement as to adapt teaching techniques accordingly.

They also help in the building of personalised learning environments using instructional data which can help them study how students can improve learning [1].

B. Facilities

IoT is not limited to data technologies alone IoT allows the control of a smart classroom's environment using smart sensors and controllers, air conditions are adjusted automatically according to the environmental conditions and lightning dimmed accordingly in alignment with natural light conditions [5].

1) Air Conditioning

Students and teachers alike benefit from the use of smart air conditioning, using sensors the air temperature and humidity are monitored, and settings are adjusted in a smart fashion to best suit the learning environment. It has been shown that optimum levels of humidity and temperature in a room enhances concentration and levels of learning [6].

2) Smart controlled windows

Windows are capable of being controlled by a smart network through the automatic adjustment with controllers and sensors, air flow is monitored in the room and windows are either opened or closed according to sensor readings. Windows are also locked at the end of teaching hours automatically ensuring the security of the building regardless of human input.

3) Lightning

Smart lighting is commonly found in smart classrooms, which aims to adjust lighting to the optimal level using sensors and controllers, lights are dimmed during the day and turned up during night hours for an optimum learning experience.

4) Noise control system

Students are exposed to numerous categories of sounds, such as noise pollution, external sounds and environmental noise research has shown that noise pollution has an adverse effect on learning and the uptake of new information, noise pollution can also affect motivation, learning capability in general and memory recall, it is generally accepted that noise pollution has a detrimental impact on the cognitive development of students [7].

Noise warning systems are commonly used in smart classrooms to alert the teacher or lecturer to excessive noise levels or can even display an instruction to quieten down if the noise of the classroom exceeds a certain threshold that is considered detrimental to learning.

C. Advantages of smart classrooms

Classrooms in the near future are not only going to be technically superior, but they are going to be equipped with smart devices as well. When designing these teaching space, academic aspects should be considered with architectural factors as well.

Smart classrooms are supposed to have all the latest inventions and gadgets in mobile computing information technology, and communication tools. They need to adapt

and follow the students' journey and transformational needs in the learning environment. [8]

Learning experience can benefit from the use of tablet technologies such as iPads. O'Malley, Lewis, & Donehower [9] observed among autistic students, that tablets could be advantageous in enhancing independent project achievement.

Using different kind of interactive tools going to make the pupils to get up on their feet and collaborate with their teachers and fellow students, making the classroom more vivid and interactive occasionally than in an old-fashioned classroom. [10] Therefore, productivity and attention-span amongst students can be increased.

An exciting benefit of technologically advanced whiteboards such as the short-throw projectors, that it can turn any surface into a smart board. [8] It can be projected onto the walls, ceiling, floor or direct to students' desks. Such device can save space and money by preventing further purchase of a screen to project onto.

Teaching and learning practice can be improved when smart boards are used correctly. In shared classrooms flicking through several board layouts and switching swiftly can be a huge time saver for the educators. Changing from a music board onto a graph math board could happen in a click of a button. Teachers can benefit from saving money on stationary supplier such as markers and precious minutes by cleaning an old-fashioned white board scrubbing it clean. [11] [12] [13]

Receiving accurate feedback is a valuable part of education. Lecturers are constantly trying to seek advice from their students to see if the pupils were happy with the lecture's content and delivery method. They are keen to know the areas, techniques they need to improve on. Recent study finds that roughly after 10 minutes students' attention begins to drop. By the end of the class, pupils remember 70% of the information given in the first ten and only 20% of the last ten minutes [11].

An ordinary classroom can be transformed into a smart one by incorporating IoT technology that analyse voices, listens during lectures and conversations, senses movements, track faces, analyse behaviours to give accurate feedback on the tutor's performance and the students satisfaction.

This way they are able to make the classes more enjoyable and sufficient for the ones participating in it, and teachers can swiftly improve their performance. [12]

The ultimate benefit comes when all the individually mentioned devices work nicely together to develop the educational and learning experience. Therefore, in a smart classroom these technologies, and all devices would be incorporated harmoniously to facilitate learning. [11]

D. Challenges

Adoption of IoT comes with huge benefits but they also come with large scale challenges to overcome, educational

institutions and smart classrooms in particular face financial issues and legislative problems, whilst governments have made efforts to incorporate smart classrooms into institutions there is still a long way to go before classrooms are seen to be fully smart capable. Other challenges are the lack of efficient and robust security protocols and standards, security is a huge challenge to IoT as each node is considered a vulnerability due to lack of encryption and other issues such as inadequate authentication and authorization procedures, [13] there is much work to be done to ensure that connections are secure and immune from sniffing attacks amongst a whole plethora of other exploitations. ICT incompetency, resource accessibility, instructor self-efficacy and inadequate preparation are other prominent challenges faced by architects and decision makers when considering IoT in smart classrooms.

Learning applications on mobile devices such as tablets and e-books are effective at making a learning experience more engaging and interactive, however there is the requirement of a high-speed internet connection to support such a high volume of network traffic in which the constant transfer of data and multimedia data demands. There is a concern that schools, which are most commonly located in rural areas, may struggle to deal with the network load given their available connection, they lack the ability to power an adequate low sensing WiFi system and miss the necessary telecommunications infrastructure to power an IoT powered classroom [14].

Whilst IoT harbours great potential there are legitimate concerns surrounding security, safety and privacy, managing such a risk requires the overcoming of many challenges. With security being the paramount issue overshadowing IoT it remains to be the most important factor affecting higher educational institutions decision to expand into it, modifications can be made to manipulate exam grades and spoof attendance working under the assumption that the student is aware of the vulnerability. Another example citing security is the unauthorised gathering of GPS data, which is hugely ubiquitous in IoT, being used in kidnapping crime [14].

By embedding sensors into primary physical environments IoT can attain a large amount of rich sensor data that accurately reflect the environment and the conditions of the activities going on, data volume tends to be very high. Scalability issues exist in the requirements to analyse, and sort said data as to find and capture information and relevant trends [15].

Questions are also raised as to the moral role that IoT plays in human lives, particularly regarding personal control, it has been shown that IoT may reduce people's autonomy and move them towards specific habits this then passes the power to corporations for financial gain, regarding the education sector itself this means the power shifts to the organizations instead of the academic professionals themselves. The dehumanization of humans interacting with machines is a legitimate concern, the issue is raised that IoT technologies in education result in the partial loss of the social element in going to school, many studies indicate the benefits of face to face student interaction benefitting a

child's social skills and positively contributing towards character building. [15].

E. The future of IoT

The future development of IoT just about to cover all areas of our everyday lives, from education to healthcare through agriculture. Most sectors "Fig. 1" are implementing changes and have been working on it a long time, just as they are planning to continue to improve it further.

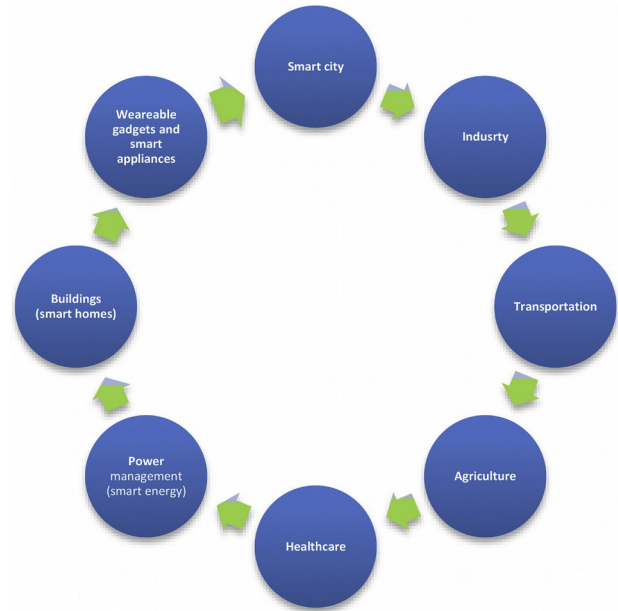


Fig. 1. Main application areas of IoT technologies

The energy sector currently is one of the most evolving areas of IoT technologies where developing solutions are concentrating on smart homes. Carrying out advanced automatization of home energy systems, such as improvements to effective demand-side management of power systems and development of smart and adaptive micro-grids. Environmental protection focuses on improving air quality by monitoring its quality with the help of IoT technology and carrying out various tests. Significant improvement is expected in healthcare practices as well by applying IoT devices. Appropriate treatments, therapy decisions, qualitative rehabilitation methods can be given to those in life-threatening stages, as predictions could be made quicker and more accurately. In the transportation sector currently, a steady transition can be observed. In the next 10 years technology will advance to a level where mainly electric, hybrid and hydrogen-based vehicles will provide almost all our transportation needs. Due to critical infrastructural concerns the most progressing IoT application area is the smart city concept as cities have been overpopulated. A much-needed change is required in this sector to deal with the crowded capitals and many other big towns. [16]

Projections for the next decade predicted to show a rise of IoT technologies by an intense amount, over 125 · 10⁹ IoT devices are expected to be connected to each other creating a smart environment to a given field. To implement these

connections most of all the internet speed need to be up to speed, in a literal sense. The speed and coverage of wireless networks is essential to efficiently implement IoT technologies [17]

The expansion of enabling technologies such as semiconductor electronics, smart phones, sensors, communications, embedded systems, cloud networking, network virtualization and software will be crucial to permit physical devices to function in shifting environments & to be connected all the time everywhere. [16] “Fig. 2” indicates the Future Development Areas in IoT by K.K. Patel. [17]

TECHNOLOGY	FUTURE DEVELOPMENT	RESEARCH NEEDS
Hardware Devices	<ul style="list-style-type: none"> •Nanotechnology •Miniaturization of chipsets •Ultra low power circuits 	<ul style="list-style-type: none"> •Low cost modular devices •Ultra low power EPROM/FRAM •Autonomous circuits
SENSOR	<ul style="list-style-type: none"> •Smart sensors (bio-chemical) •More sensors (tiny sensors) •Low power sensors •Wireless sensor network for sensor connectivity 	<ul style="list-style-type: none"> •Self powering sensors •Intelligence of sensors
Communication Technology	<ul style="list-style-type: none"> •On chip antennas •Wide spectrum and spectrum aware protocols •Unified protocol over wide Spectrum •Multi-functional reconfigurable chips 	<ul style="list-style-type: none"> •Protocols for interoperability •Multi-protocol chips •Gateway convergence •On chip networks •Longer range (higher frequencies – tenths of GHz) •5G developments
Network Technology	<ul style="list-style-type: none"> •Self aware and self organizing networks •Self-learning, self-repairing networks •IPv6-enabled scalability •Ubiquitous IPv6-based IoT deployment 	<ul style="list-style-type: none"> •Grid/Cloud network •Software defined networks •Service based network •Need based network
Software and algorithms	<ul style="list-style-type: none"> •Goal oriented software •Distributed intelligence, problem solving •User oriented software 	<ul style="list-style-type: none"> •Context aware software •Evolving software •Self reusable software •Autonomous things: •Self configurable •Self healing •Self management
Data and Signal Processing Technology	<ul style="list-style-type: none"> •Context aware data processing and data responses •Cognitive processing and optimization •IoT complex data analysis •IoT intelligent data visualization •Energy, frequency spectrum aware data processing 	<ul style="list-style-type: none"> •Common sensor ontology •Distributed energy efficient data processing •Autonomous computing
Discovery and Search Engine Technologies	<ul style="list-style-type: none"> •Automatic route tagging and identification management centers •On demand service discovery/integration 	<ul style="list-style-type: none"> •Scalable Discovery services for connecting things with services
Security & Privacy Technologies	<ul style="list-style-type: none"> •User centric context-aware privacy and privacy policies •Privacy aware data processing •Security and privacy profiles selection based on security and privacy need 	<ul style="list-style-type: none"> •Low cost, secure and high performance identification/authentication devices •Decentralized approaches to privacy by information localization

Fig. 2. Future development areas in IoT

IOT uses technology to connect physical objects to the Internet. In coming years, the components needed for the implementation and growth of IoT such as tracking and control mechanisms, sensing devices, must be significantly more affordable. [16] Present day it is often hard to find the fundings for the desired technological updates which can put a hold on future developments. With rapid progression often there is a potential and specific drawback that needs to be analysed in depth. As we looking to implement billions of devices in the near future, it is important that we address the challenges as it can impact the population. [17]

F. The evolution of smart classrooms

There are huge developments for smart classrooms on the horizon, advances in bio sciences and machine learning have the potential to play a role in improving the vision of personalized and smart education. A key objective of smart learning is to replace the traditional measures of education i.e. scores and quizzes with a real time snapshot of the student’s state of mind, such is possible with the use of neuro technology. These real time signals can be used to

change and adapt instructional materials in order to maximize student performance [18].

Students readiness to learn to knowledge, drowsiness level, stress level and learning speed are among some of the signals that could be monitored using such technology and to consequently improve learning, there is however a long way to go in regards to this development as there are advances needed in neuroscience and wearable sensor technology necessary to fulfil the requirements of real time signal monitoring.

There are however significant developments in wearable neurotechnology that can enable complex application integration and predict cognitive processing to a certain degree, these advancements combined with the evolution in machine learning and classification, means analysis of data streaming from the wearable devices has become practical [18]. They do however come with a series of challenges that are yet to be overcome in order to make the implementation of said technology achievable.

Artificial intelligence (AI) could offer new types of services based on the integration of virtual reality (VR) and augmented reality (AR). VR is an interaction with the virtual world through technology that offer the user the opportunity to see and sense things, whereas AR is the real world with a virtual world overlay, these technologies combined with robotics can bring a new stage of evolution for the educational field [19, 20].

5G networking will also be implemented amongst IoT expansions within smart classrooms offering a new level of data transfer essential for data sensors when transferring their data to and from network devices. According to the 5G white paper, a downlink speed of 300 Mbps is said to be possible with a 50Mbps uplink speed, with an end to end latency from 10ms to 1ms, these are speeds possible of addressing the requirements of any smart classroom.

It will be made possible for live interactive presentations to take place with a student or teacher wearing haptic gloves, an intelligence driven system provides instant feedback through the haptic gloves alongside a feedback visualization dashboard in real time transferring information on how to adapt voice intonation, body language or any other nonverbal behaviour to be a more effective teacher or presenter. A system that accomplishes sophisticated tasks within a fraction of a second makes this possible by digitizing the multi modal audio/visual data of the presentations and going onto transfer them to the cloud through a 5G or highspeed WiFi network then processing them to determine a behavioural state using intensive algorithms. The evolution of smart classrooms is ongoing with the field of neuro science and haptic technologies taking the spotlight.

IV. CONCLUSION

In this study various technologies were introduced as being used in classrooms, they were then compared with smart technologies utilized by IoT and smart classrooms and their features and merits were discussed. IoT and the shaping of the smart learning environment has come a long way with

big data analysis, learning analytics and smart wearable devices all acting as components to provide a more interactive, immersive environment for students and teachers alike. Smart facilities were also discussed namely, smart windows, lighting, air conditioning and noise control systems and their merits noted. The future of IoT as a general note was then highlighted with the evolution of smart classrooms with potential future technologies being cited and described.

Challenges to implementing IoT in classrooms was also discussed such as networking infrastructure which has come on leaps and bounds and possesses the capacity, using 5G networking, to accommodate for the heavy network demand IoT places on school networks and should hold up for years to come. There is however the question of affordability, especially for public sector schools who are limited to government legislation and policy, alongside the issue of security, safety and privacy, all discussed in this study. The 4th technological revolution is at hand and technologies are surpassing and exceeding their evolutionary timelines, there has never been a more appropriate time to consider implementing smart technologies in the classroom, as they are shown and proven to be effective at enhancing the interactivity and immersion of learning material for students, improving the learning experience as a whole.

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