ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA (ASEA)

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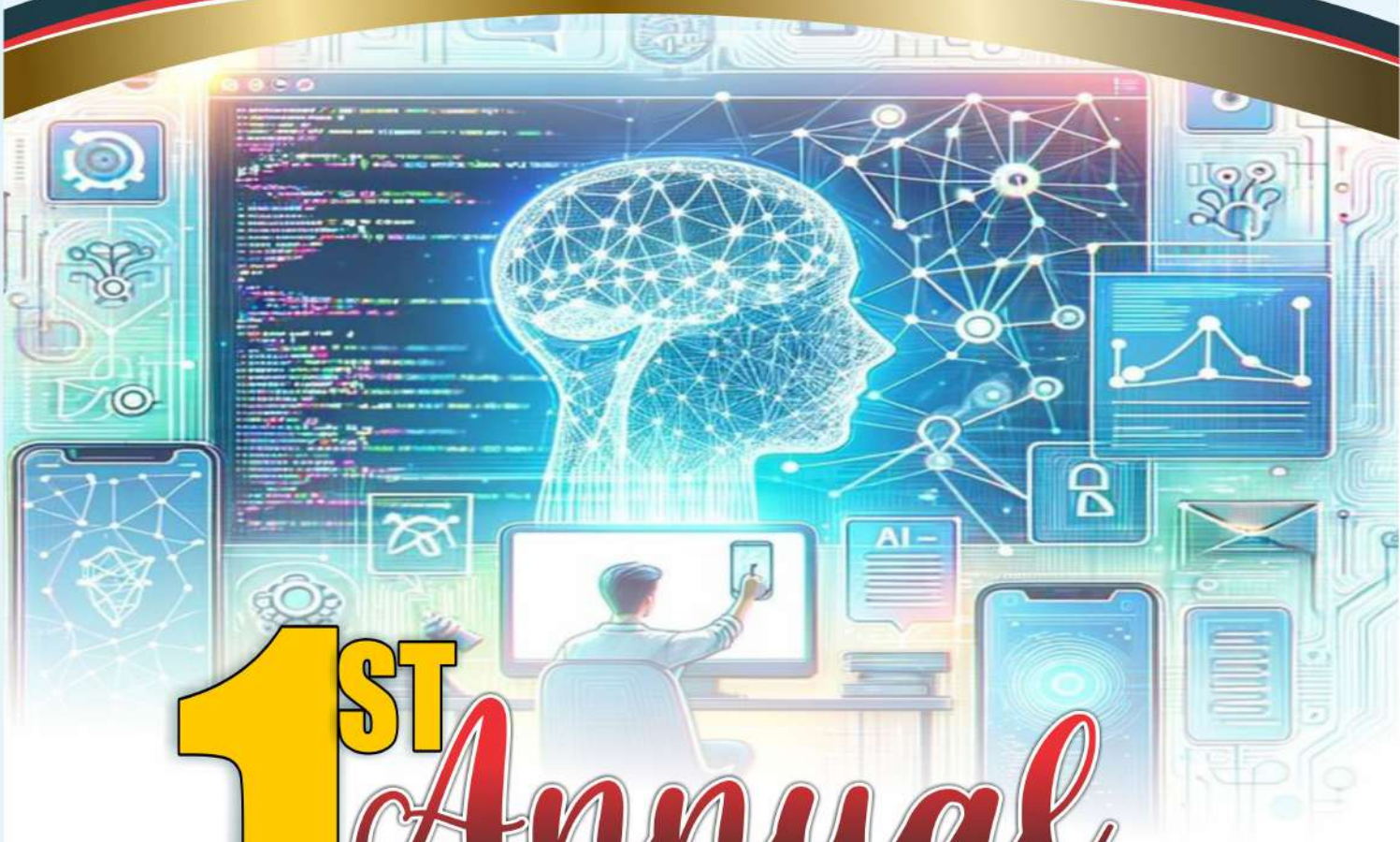
SCIENCE EDUCATORS AND DIGITAL LITERACY IN THE 21ST CENTURY



1ST Annual CONFERENCE

PROCEEDINGS 2025

Editor
Prof. Josephine N. Okoli

SCIENCE EDUCATORS AND DIGITAL LITERACY IN THE 21ST CENTURY
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ASSOCIATION OF SCIENCE EDUCTORS ANAMBRA (ASEA)

THEME: SCIENCE EDUCATORS AND DIGITAL LITERACY IN THE 21ST CENTURY

1ST ANNUAL CONFERENCE PROCEEDINGS, 2025

10- 12th July, 2025

Editor

Prof. Josephine, N. Okoli

Printed in Nigeria by:

Love Isaac Consultancy Services
No 1 Etolue Street, Ifite Awka, Anambra State, Nigeria
+234-803-549-6787, +234-803-757-7391

Published in June, 2025
ISBN: 978-978-695-937-5

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MERITORIOUS AWARD
CITATION OF Dr SAMUEL ALFAYO BOH

It is my pleasure and singular honour to be called upon to read a citation on one of the eminent Doctor that the family of Alfayo has ever produced.

People are not chosen for their comfort, they most often to prepare for a life of self sacrifice and even sufferings on behalf of other. And most often their calling is not for privilege but for service. Whichever prism you use in view him, Dr Samuel Alfayo Boh a class teacher of high repute, a man of integrity and fear of God, sacrifices and service for the betterment and advisement of humanity.

May, 18, 1969 marked the beginning of the steadily progressive son of Boh colored mother and the Shongomite father. This account of this childhood and youth in Gombe State shows the prince he had to pay for such a birth. It did not take long before he was revealed as a man of vision and mission as every step he took in both early life and now was clogged with success, and a wide breath of accomplishment.

Dr.Samuel Alfayo Boh spends is early life in Boh with his parent. He attended Boh primary school from 1976 to1984 exposed his qualities as a gifted child enable him to proceed to Government Science Secondary School Kaltungo 1984 to 1987,Teachers College Gombe 1988 to 1990 the exceptional this qualities made way for him to enlist to College of Education Azare 1993 where he bagged National Certificate in Education (NCE) while in Azare, he was elected parliamentary student union 1994 to 1995 session and thereafter in the year 1987, he proceeded to famous University of Maiduguri Borno State and had a Bachelor of Education and passed with flying colours in 2000. Diploma in World Evangelism Mission Training Institute in Borno State in 1999. In 2001, the indefatigable Samuel was drafted in to the National youth service scheme in Tsafe, Zamfara State his service witnessed a continued story of one success after another like the Nehemiah of the Holy Bible. As a man who fully understand what benefits education could bring his way when tapped. Dr Samuel did not hesitate to define where he was headed for in that direction. In 2004, he gain admission to University of Maiduguri, Borno States as an intelligent

student, he graduated in 2008 with Master of Education in Curriculum and Instruction (M.ED).Diploma and Certificate in computer 2009. In the year between 2013 to 2016 he bagged Masters in Guidance and Counseling in Theological Seminary College Kaltungo in Gombe State. Moreover, the influence this celebrated academia exerted on him equipped him to master the techniques of research, the canons of interpretation and reconstruction of academic research, the craft and skills involved and teacher – students relationship in 2010 he proceeded to one of the best University in Nigeria University of Nigeria Nsukka in Enugu State and come out with Doctor of philosophy (Ph.D) in Curriculum and Instruction.

A man with a formidable profile charismatic personality, Dr Samuel is indeed an achieve per excellence he has not only carved a niche for himself, but has also made name and reputation in Nigeria. He has always impacted positively in the lives of everyone he meets. He has also shown high sense of professionalism and dedication to the service of humanity. On several occasion Samuel has interrupted his travels to attend to civilian, accident victims and he has truly saved a lot of lives.

Dr. Samuel Alfayo Boh started his civil service career as a classroom teacher; he had a little starting with the noble teaching profession. In 1996 he took appointment with Boh primary school, Labeke primary school in 1997, Kulishin primary school 1999, Pivotal Teachers Training Programme Lapan in 1999. In 2000 He moved to Government Day Secondary School Boh. In 2000 Tutor Senator T.U. Wada Educational Emancipation Scheme. Presently, lecturer with Federal University Kashere, in the Department of Educational Foundations

Dr. Samuel is a versatile personality of note and a man of many parts. He is fondly referred to as sport, Author and a born teacher of good repute. In his romance with great academics, he has received more than twenty awards, member of many associations, he has presented more than thirty academic papers in both international and national journals, he has published Ninety journals, sixteen book chapters, he has written eight books, presently chairman board of governors Jim Collis Kufai, fellow members of more than seven associations, former permanent commissioner sports commission Gombe State, chairman and secretary of many association, He is happily married to Mrs. Abigail Samuel and blessed with many children.

Having described himself as an enterprising person who has excellence attached to his name, Dr Samuel Alfayo Boh evinces a friendly disposition towards his students. He is a strong advocate of treating students with understanding and affection, Dr. Samuel incontestably mentors, counsels, reprimands, sympathizes and assists his young and old alike. Some of his students describe him as a luminous teacher whose passion for academic scholarship is infectious and whose pedagogical principle skills and friendly disposition are so admirable and endearing that attendance at his lectures is always high and far outstrips most others.

Ladies and gentlemen, Dr. Samuel Alfayo Boh is a small figure on the physical appearance. It is my great honour and privilege to call on this academic repute, erudite, scholar, indefatigable and inspirational mentor, community lover, and motivator ardent love of Shongomite culture and humanist to graciously joint the chairman and other for the formal presentation of this fabulous awards to acknowledge to celebrate his hard word, disciplines, kindness, humanness and commendable role he is playing in the academic careers and character-building

FOREWORD

It is with profound pride and optimism that I write this foreword to the maiden Book of Conference Proceedings of the Association of Science Educators Anambra State a timely and significant academic documentation that captures the robust engagements, research contributions, and transformative ideas presented at the 1st Annual Conference of the Association, scheduled for July 10, 2025, in Awka, Anambra State, Nigeria.

The conference, with the theme "Science Educators and Digital Literacy in the 21st Century," could not have come at a more opportune moment. In an age where digital transformation is rapidly redefining education, economy, and society, the role of science educators in equipping learners with not only scientific knowledge but also digital competencies has become more critical than ever. The conference offered a strategic platform for scholars, researchers, policy makers, and practitioners to interrogate, share, and shape new pedagogical paradigms that incorporate digital literacy into the fabric of science education.

In his address of welcome, the Acting President of ASEA, Dr. Johnbosco O.C. Okekeokosisi, delivered a compelling call to action. He set the tone by acknowledging the historical importance of the event and the noble mission of ASEA to champion science education across Anambra State and beyond. His words reflected a clear vision of collective progress, innovation, and institutional synergy. Most notably, Dr. Okekeokosisi emphasized that digital literacy in science education is not merely about embracing technological tools but about empowering both educators and learners to critically engage, create, and transform scientific knowledge for societal advancement.

This compilation of conference proceedings is more than a record of presentations—it is a testimony to the enduring commitment of Nigerian science educators to adapt to global educational trends. With insightful keynote and lead paper presentations by eminent scholars such as Prof. Cecilia O. Ekwueme and Prof. Telima Adolphus, participants were exposed to a breadth of ideas, models, and classroom innovations. These contributions are now immortalized in this volume, accessible to researchers, policymakers, and education stakeholders worldwide. The articles by contributors are of quality standard and intimately related to the conference theme.

The proceedings are also a celebration of collective effort. Dr. Okekeokosisi rightly acknowledged the contributions of past leaders of STAN, the Executive Principal of Igwebuike Grammar School, the Local Organizing Committee, and institutional partners who ensured the success of this pioneering event. Their efforts reflect a shared belief in the transformative power of science education when driven by vision, collaboration, and strategic digital integration.

This book also symbolizes the maturity and forward-thinking disposition of ASEA. With its proceedings published online in the Association's official website (www.jisepublications.org), ASEA is setting a benchmark for academic visibility, accessibility, and global relevance. The initiative aligns perfectly with the conference theme—leveraging digital platforms for knowledge dissemination.

As readers engage with the rich content within this publication, it is my hope that they find not only knowledge but also inspiration to further the cause of digital transformation in science education. May this volume serve as a resource, a reference, and a rallying point for continued innovation, research, and excellence in digital literacy, science teaching and learning.

Prof. Marcellinus C. Anaekwe
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National Open University of Nigeria,
Abuja.

PREFACE

Digital literacy in the 21st century is crucial for science educators to effectively teach and prepare students for a rapidly evolving scientific and technological world. Science educators must embrace digital tools and resources to enhance their teaching methods and foster students' scientific literacy, critical thinking and problem-solving skills. This includes leveraging online platforms, using educational technologies and digital content to create engaging and meaningful learning experiences.

In this conference proceedings efforts has been made towards promoting the use of digital tools in science education.

Prof. Josephine N. Okoli
Science Education Department
Nnamdi Azikiwe Universitry, Awka,
Anambra State, Nigeriascience

ADDRESS OF THE ACTING PRESIDENT OF ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA (ASEA), DR. JOHNBOSCO O.C. OKEKEOKOSISI, AT THE OPENING CEREMONY OF THE 1ST ANNUAL CONFERENCE HELD IN AWKA, ANAMBRA STATE, NIGERIA ON 10TH JULY, 2025

Theme: "Science Educators and Digital Literacy in the 21st Century"

Distinguished Guests,
Mother of the Day, and Executive Provost of the Federal College of Education (Technical), Umunze, Prof. Tessy O. Okoli
Past and Immediate Past Chairmen of the Anambra State Chapter of the Science Teachers Association of Nigeria (STAN), Prof. C.V. Nnaka, Dr. Christiana U. Ezenduka Past and Immediate Past Secretary of the Anambra State Chapter of the Science Teachers Association of Nigeria (STAN), Dr. Chinwe B. Njelita, Mr. Kingsley N.C. Ezeokeke
The Executive Principal of Igwebuike Grammar School, Awka, Mrs. Amaka Ifebili
Our Esteemed Keynote and Lead Paper Presenters, Profs: Cecilia O. Ekwueme, Telima Adolphus
Meritorious Awardee, Dr. Samuel Alfayo Boh
Representatives of Educational Institutions, Pharm. Adauzoh C. Joe-Obasi
The Conference Planning Committee
The Local Organizing Committee (LOC),
My Fellow Science Educators,
Ladies and Gentlemen.

It is with deep humility and immense pleasure that I stand before you today as the Acting President of the Association of Science Educators Anambra (ASEA), to welcome you all to this historic gathering — the **1st Annual Conference** of our noble Association, taking place here in the vibrant capital city of Awka, Anambra State.

This moment marks a milestone in the life of our Association and in the educational landscape of our dear state. Today, we have gathered not just to deliberate on academic issues, but to collectively reflect on and shape the role of science educators in a rapidly changing digital world. The presence of each one of you here is a testament to your dedication to the advancement of science education in Nigeria, and in particular, in Anambra State.

Let me begin by extending heartfelt gratitude to our **Mother of the Day**, the erudite and distinguished **Executive Provost of the Federal College of Education (Technical), Umunze**, for honoring our invitation. Your presence is a great source of inspiration, and we are immensely grateful for your unwavering support towards science and technical education in the state. The Host and Board of Directors, Prof. Josephine N. Okoli, Prof. Isaac N. Nwankwo, Prof. M.C. Anaekwe

Chairman of the occasion Ass. Prof. Peter I.I. Ikokwu

To the **Past Chairman and Immediate Past Chairman of Anambra State STAN**, we salute you. You laid the foundation for excellence and integrity in science education upon which ASEA continues to build. We are proud to carry forward the torch of progress you lit. Your legacies continue to motivate and guide our mission as science educators.

We also sincerely appreciate the **Executive Principal of Igwebuike Grammar School, Awka**, for the enormous and selfless support towards the successful hosting of this conference. Your generosity and logistical assistance have played a crucial role in bringing this vision to reality. We are proud to host this conference within your institution, and we thank you for embracing the ASEA family.

Special thanks also go to our **Keynote and Lead Paper Presenters**, whose scholarship and insight will surely enrich our understanding of the conference theme: *"Science Educators and Digital Literacy in the 21st Century."* You are the thought leaders that will help us navigate this complex but exciting intersection between pedagogy and technology.

Meritorious Awardee, **Dr. Samuel Alfayo Boh**, whose contributions to teaching and learning in tertiary institutions lead to the foundation of our members.

The **representatives of educational institutions**, both public and private, we acknowledge your partnership and presence. Your contributions, ideas, and institutional support are essential in sustaining quality science education. Together, we can foster a generation of scientifically literate citizens equipped for the demands of the 21st century.

Let me also specially recognize the tireless efforts of the **Local Organizing Committee (LOC)**. You have worked round the clock, attending to logistics, communications, hospitality, and a host of behind-the-scenes responsibilities. This conference would not be possible without your selfless commitment. I say, "Well done!"

This conference has its theme **"Science Educators and Digital Literacy in the 21st Century".** The theme is very apt considering the fact that we are in the digital age. Thus, the committee on conference looked inward to provide this conference theme for science educators to understand, educate, re-educate, write and deliberate on the effective use of digital tools – technologies in our present time for effective instructional delivery. Participants will be taken through hands-on and minds-on activities in various sessions and they will find the conference package very rewarding. I invite you to pay attention during keynote address to be presented by Prof. Cecilia O. Ekwueme, the Dean Faculty of Science Education, University of Calabar, Cross-River State, Nigeria. Your continuous attention is also needed during the lead paper presentation of Prof. Telima Adolphus of Rivers State University, PortHarcourt, Nigeria.

To all **participants** – educators, researchers, students, policy makers – thank you for making out time to be here. Your presence signifies hope for the future of science education. I urge you to make the most of this gathering by networking, exchanging ideas, and exploring new strategies to embed digital literacy in science classrooms and curricula.

As we delve into this conference theme, let us remember that digital literacy is not just about the use of devices or softwares. It is about empowering both teachers and learners to navigate, create, and critically evaluate digital content. It is about transforming science education into an interactive, engaging, and accessible experience that prepares our students for global competitiveness. We must rise to this responsibility with courage, collaboration and innovation.

As we officially declare this conference open, let us do so with a shared sense of purpose and vision. Let us reflect deeply, discuss intelligently and leave this gathering better equipped to build a technologically savvy and scientifically vibrant society.

Ladies and Gentlemen, it may interest us to note that this young growing association has an online Journal, Electronic Book (e-book) and Conference Proceedings. The E-Book and Conference Proceedings were hosted online at the association's website (jisepublications.org) for its visibility. It is obvious that this association has come to stay. To God be the glory.

Once again, I welcome you all to the 1st Annual Conference of the Association of Science Educators Anambra (ASEA). May our deliberations be fruitful, and may the bonds we forge here today grow stronger for the benefit of science education in our state and beyond.

Thank you, and God bless you all.

Dr. Johnbosco O.C. Okekeokosisi
Federal College of Education (Tech) Asaba,
Delta State, Nigeria
Acting President, ASEA
10th July, 2025

PAPER 9

INTERNET OF THINGS ENABLED SMART ENVIRONMENTAL MONITORING SYSTEM BASED ON THE ESPRESSIF SYSTEM 32 MICROCONTROLLER

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Nwafor Orizu College of Education, Nsugbe, Anambra State, Nigeria.

Abstract
This study presents the development of a low-cost, real-time environmental monitoring system leveraging the Internet of Things (IoT) paradigm. The proposed solution integrates readily available and economical hardware components and open-source software platforms. At the core of the system is an ESP32 microcontroller equipped with sensors capable of measuring air, temperature, relative humidity, atmospheric pressure and particulate matter concentration. The sensor data is collected and processed by the microcontroller, which transmits it wirelessly to the Thing Speak IoT cloud platform. ThingSpeak provides a user-friendly interface for data visualization, remote monitoring and control. The cloud-based architecture enables accessing environmental data from any internetconnected device, facilitating real-time monitoring over a wide geographic area. The developed system exhibits low power consumption, making it suitable for battery-operated deployments. Initial testing of the prototype was conducted by deploying it alongside a commercial environmental monitoring station, demonstrating its feasibility and potential for scalable implementation in various domains such as smart cities, precision agriculture and industrial process monitoring. The proposed approach offers a flexible and cost-effective solution for environmental sensing and monitoring applications.

Keywords: Internet of Things, Environmental monitoring, ESP32 microcontroller

Introduction

Environmental monitoring is crucial for understanding and protecting our natural ecosystems. It involves the systematic measurement and observation of various environmental parameters, such as air quality, water quality, soil health and biodiversity. With the rapid advancement of technology, new approaches to environmental monitoring have emerged, offering more efficient, cost-effective and real-time solutions. (Shinde, Tasgaonkar & Garg, 2018). One such approach is the integration of the Internet of Things (IoT) technology with environmental monitoring systems. IoT refers to the interconnection of physical devices, sensors and networks that can collect and exchange data over the Internet. By leveraging IoT, environmental monitoring can be conducted remotely, enabling real-time data collection, analysis and decision-making. The use of IoT in environmental monitoring typically involves deploying a network of sensors that can measure various environmental parameters. (Catelani, Ciani & Bartolini, 2020). These sensors are equipped with microcontrollers and wireless communication capabilities, allowing them to transmit data to a central system or cloud platform for processing and analysis. The advantages of using IoT for environmental monitoring are numerous. Real-time data collection enables prompt detection of environmental changes or anomalies, facilitating timely interventions. Additionally, IoT-based systems can cover large geographical areas, reducing the need for manual data collection and increasing the efficiency of monitoring efforts. Furthermore, the data collected can be analyzed

using advanced algorithms and machine learning techniques, providing valuable insights and enabling predictive modeling. Despite the numerous benefits, implementing IoT-based environmental monitoring systems presents challenges, such as ensuring data security, privacy and system reliability. However, with continuous research and development, these challenges can be addressed, paving the way for more widespread adoption of IoT in environmental monitoring applications. (Carducci, Monti & Schraven 2019).

Statement of the Problem

Environmental degradation and pollution have become pressing global challenges, necessitating real-time and continuous monitoring of environmental parameters such as air quality, temperature, humidity and water quality. Traditional environmental monitoring systems are often expensive, bulky, power-intensive and limited in their scalability and accessibility. Furthermore, many of these systems lack the capability for remote monitoring and data transmission, resulting in delayed responses to environmental hazards and inefficient data management (Park, Kim, & Lee, 2020).

In developing regions, the deployment of conventional monitoring systems is further hindered by infrastructure constraints, high costs and the need for frequent manual intervention. These limitations impede the timely detection of environmental changes, which is critical for effective policy response, public health protection and sustainable development (Kodali & Valdas, 2018).

Given these challenges, there is a growing need for a low-cost, energy-efficient and easily deployable solution that enables real-time, remote monitoring and reporting of environmental conditions. The internet of things (IoT), when integrated with microcontrollers like ESP32, offers a promising approach to address these limitations. However, despite the potential, practical implementations of such systems remain limited, especially in resource-constraint settings.

This study, therefore seeks to develop an IoT based smart environmental monitoring system using the ESP32 microcontroller to provide a cost-effective, scalable and remotely accessible solution for real-time environmental data collection and analysis.

Purpose of the Study

The purpose of this study is to design and develop a smart environmental monitoring system using the ESP32 microcontroller integrated with internet of things (IoT) technologies. The system aims to enable real-time data collection, transmission and analysis of key environmental parameters such as temperature, humidity, air quality and other relevant indicators. By leveraging the low-cost, low-power capabilities of the ESP32 and the connectivity features of IoT. The study seeks to provide an efficient, scalable and accessible solution for continuous environmental monitoring. Ultimately, the system is intended to support proactive environmental management, data-driven decision-making and early detection of harmful environmental conditions in both urban and rural settings.

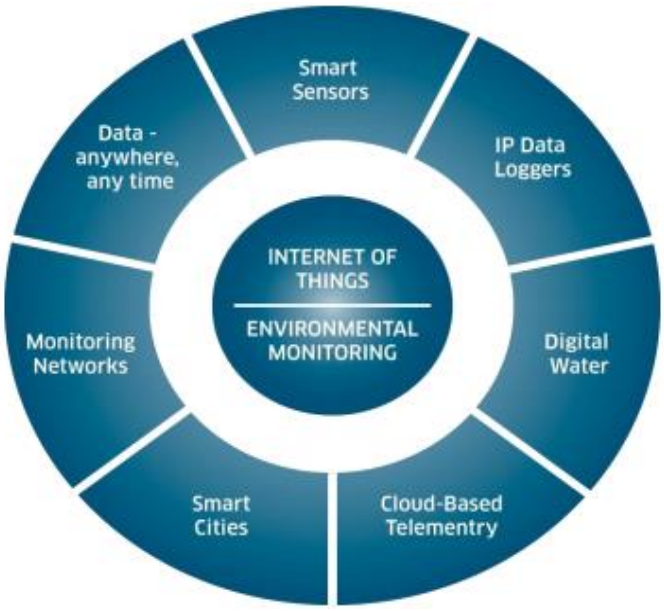

Fig 1: Environmental Monitoring

Proposed System

The proposed system is an Internet of Things (IoT) based environmental monitoring platform designed to provide a flexible, scalable and user-friendly solution for monitoring various environmental parameters in real time. At its core, the system utilizes a low-power and cost-effective microcontroller, such as the ESP32, acting as the central processing unit. This microcontroller is responsible for interfacing with a range of environmental sensors, processing data and communicating with a cloud platform. (Mishra, Prajwal & Niveditha, 2020). A key component of the system is the integration of various environmental sensors capable of measuring parameters like temperature, humidity, air quality (volatile organic compounds), soil moisture and noise levels. These sensors are carefully selected based on their accuracy, reliability and compatibility with the chosen microcontroller. (Hanes, Salguiero, Grossetete, Barton & Henry, 2017 & Acevedo, 2016). Depending on the deployment scenario, the system can be powered by a rechargeable battery pack, solar panels or a combination of both, ensuring reliable and sustainable operation. The microcontroller is programmed with optimized firmware that handles sensor data acquisition, preprocessing and communication with a cloud-based IoT platform. The system leverages platforms like Thing Speak for data storage, visualization and remote monitoring. These platforms offer user-friendly interfaces, real-time data visualization and the ability to set alerts and notifications. Furthermore, the cloud platform is accessible through mobile applications and web interfaces, allowing users to monitor environmental data, set thresholds and receive alerts remotely (Seneviratne, 2018).

System Design

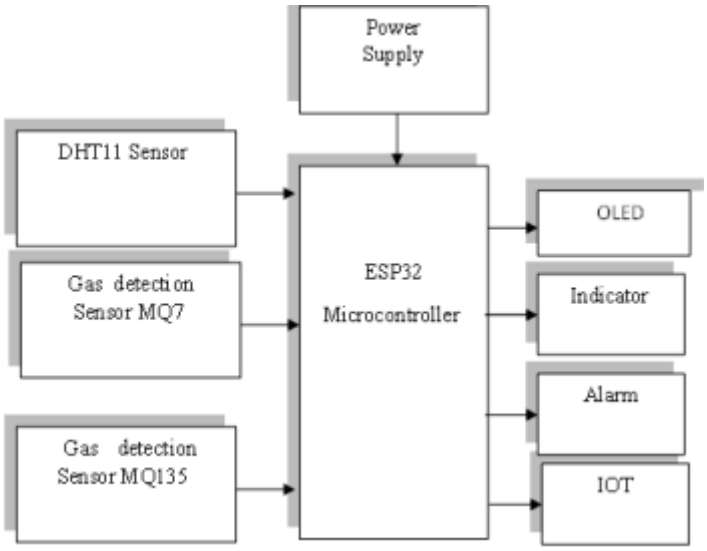

Fig 2: Block Diagram

Components description

1. **DHT11 Sensor**

Fig 3: DHT11 Sensor

The DHT11 is a low-cost digital temperature and humidity sensor. It consists of a capacitive humidity sensor and a thermistor to measure the surrounding air and it outputs a digital signal on a single wire that can be read by a microcontroller, such as an Arduino or Raspberry Pi. The sensor provides relatively accurate readings for both temperature and humidity, although it's not as precise or fast as more expensive sensors like the DHT22 or the BME280. It's commonly used in simple environmental monitoring applications due to its affordability and ease of use (Nikolov & Nakov, 2019).

2. **MQ-7 Gas Sensor**

Fig 4: Gas Sensor (MQ-7)

The MQ-7 is a carbon monoxide (CO) gas sensor. It's a small module that detects the presence of carbon monoxide gas in the air and outputs an analog voltage signal that varies based on the concentration of CO. This sensor is commonly used in gas detection systems, air quality monitoring devices and safety equipment. The MQ-7 sensor operates on the principle of a chemical reaction between CO and the sensor's internal electrodes, which changes the sensor's conductivity. This change in conductivity alters the output voltage of the sensor, allowing the measurement of CO concentration. (Harmancioglu, *et al*., 2003).

3. MQ-135 Air Quality Sensor

Fig 5: MQ-135 Air Quality Sensor

The MQ-135 is a gas sensor that can detect a variety of air pollutants and harmful gases. It is designed to sense ammonia (NH_3), nitrogen oxides (NOx), benzene, smoke and carbon dioxide (CO_2) among other gases. The MQ-135 works by utilizing a tin dioxide (SnO_2) material that changes resistance when exposed to the gases it is sensitive to. The more pollutants present in the air, the lower the resistance becomes across the sensor. This air quality sensor outputs both an analog voltage and a digital signal corresponding to the detected gas levels. The analog output voltage ranges from 0V for clean air up to around 5V for high gas concentrations. The digital output is just 0V or 5V based on whether gases exceed a set threshold level. One key advantage of the MQ-135 is its ability to detect multiple gases using a single sensor, rather than needing separate sensors for each gas type. However, it cannot distinguish exactly which specific gases are present. The MQ-135 requires a few seconds of pre-heating before accurate measurements can be taken. It is a low-cost sensor that is often used in air purifiers, carbon dioxide monitorsand other indoor air quality systems. Proper calibration is required for precise gas level readings. (Park, *et al*., 2020 & Abdullah, Sudin & Ajit, 2018).

4. ESP32 Microcontroller

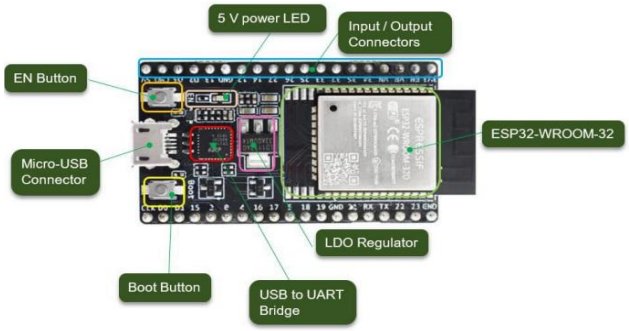

Fig 6: The Main Blocks of the ESP32 Board

The ESP32 (which stands for Espressif 32) board comes with a powerful WROOM-32 modulehaving capabilities like 802.11b/g/n WiFi /BT 4.0 /BLE. The chip consists of a dual-core

processor that can be controlled individually, operating at 240 MHz, 520KB of SRAM.ESP32 is a low-cost and low-power SoC (System-on-Chip) with Wi-Fi and Bluetooth capabilities;it also extends the number of GPIO pins from 17 to 36, the number of PWM channels per 16 and is equipped with 4MB of flash memory. You can connect your phone via Bluetooth to the ESP32 module easily. Using the Wi-Fi feature, you can use ESP32 to access weather information, time and sensor data remotely. The ESP32 board is similar to the Arduino board with more advanced features. You can program ESP32 the same way you program Arduino. The ESP32 consumes low power, making it a good candidate for battery-driven applications. It's also more powerful and faster than Arduino. ESP32 was developed by a Chinese semiconductor company called Espressif Systems. ESP32 was introduced as a successor to ESP8266. You will still see a lot of projects using ESP8266 for IoT applications. (Babiuch, Foltynek, & Smutny, 2019)

Micro-USB connector supplies power to the ESP32 board. It is also an interface between your computer and the ESP32 module. It is a Micro USB connector.

ESP32 Development Boards will have one of the ESP32 SoC. You will find the name engraved using a laser on the part. The one in the image is ESP32-WROOM-32.

EN Button – EN button is the reset button for ESP32. If you want to reset the ESP32, press the EN button momentarily and release it.

BOOT button – The boot button helps to put ESP32 into software upgrade mode.

5V LED will be ON as long as a 5V source is available. It is used to indicate power availability. It will glow if you connect ESP32 to PC via USB or supply an external 5V.

GPIOs pins of ESP32 are brought out on the I/O connector. Pins are available on the connector for all peripherals, such as ADC, DAC, SPI, I2C, PWM, etc. The I/O connector helps a lot in breadboard prototyping as well.

LDO regulator converts the input 5V into 3.3V at which ESP32 operates.

USB to UART Bridge is an IC which acts like a bridge between your PC and the ESP32 chip. It converts the data from the PC over USB to serial data, which ESP32 can understand. It supports high speed data transfer and is not a bottleneck for ESP32 programming and communication. (Ibrahim & Ibrahim, 2017).

5. OLED

Fig 7: OLED

OLEDs are also more energy-efficient than LCDs, especially when displaying darker images or videos. Since OLEDs only consume power for the pixels that are turned on, they can save significant amounts of energy when displaying dark scenes or images with large black areas. OLED displays are generally thinner and lighter than LCDs because they don't require a backlight unit. This makes them ideal for use in portable devices like smartphones, tablets and wearable's, where size and weight are important considerations. (Goyal, Balamurugan, Peng & Jat, 2019).

6. Buzzer:

A buzzer is an electronic component used to generate audible sound signals. It typically consists of a piezoelectric element that vibrates when an electric current is passed through it, producing sound waves. Buzzer modules are commonly used in various applications for indicating events, warnings, alarms or user notifications. They are often found in electronic devices such as alarm clocks, timers, security systems and electronic games. Additionally, they are widely used in DIY projects and prototyping, especially in combination with microcontrollers like Arduino or Raspberry Pi. (Goyal, *et al.,* 2019).

Fig 8: Buzzer

7. Light Emitting Diode (LED)

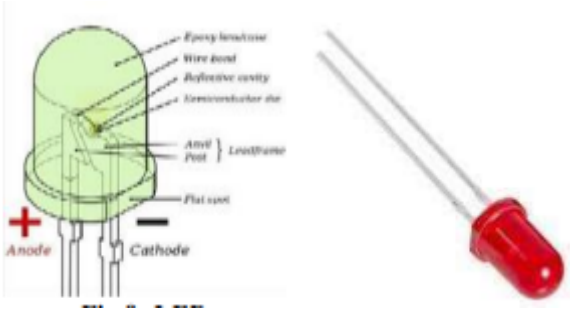

Fig 9: Light Emitting Diode (LED)

LEDs also have a compact design and can be made extremely small. They come in various colors depending on the semiconductor materials used, including red, green, blue and white LEDs. By combining different colored LEDs, it's possible to produce millions of color shades. LEDs are widely used today in electronics display screens, traffic lights, vehicle brake lights, flashlights and general lighting applications. As the technology improves and costs decrease, LEDs are replacing conventional lighting more and more due to their energy savings and long operational lifetimes. (Hanes, Salguiero, Grossetete, Barton & Henry, 2017).

8. ThingSpeak Cloud Platform

ThingSpeak is an Open-source Internet of Things (IoT) platform that allows you to collect, store, analyze and visualize sensor data in real time. It also allows you to build interfaces for controlling and monitoring various hardware projects using a mobile app or a web browser. It provides a user-friendly environment for creating intuitive interfaces with widgets like buttons, sliders, graphs and displays, which can be easily arranged and customized onThingSpeak app. It’s often used with devices like Arduino, ESP8266, ESP32 Microcontrollers and Raspberry pi. (Seneviratne, 2018).

Key Features of ThingSpeak are:

- Data Collection: Receive data through HTTP or MATT from sensors and Internet of Things (IoT) devices.
- Data Storage: Stores time-stamped data in channels (private or public).
- Data Visualization: Graphs, Charts and other visual tools for monitoring data
- MATLAB Analytics: Integrated MATLAB support for advanced data analysis and alerts
- Real-time Alerts: Trigger actions or send notifications when data crosses thresholds.

Working

The system employs an ESP32 microcontroller as the main processing unit. This low-power microcontroller is interfaced with various environmental sensors including a temperature and humidity sensor, an air pressure sensor and a particulate matter sensor. The ESP32 reads data from these sensors periodically and transmits it wirelessly to the Thing Speak cloud platform over a Wi-Fi connection. The ThingSpeak cloud acts as the central repository, storing the incoming sensor data from the ESP32 node. It provides a user-friendly web interface where the environmental parameters can be remotely monitored and visualized in real time through graphical dashboards accessible from any internet-connected device. The cloud platform also enables setting up alerts and notifications based on user-defined thresholds for the monitored parameters.

Implementation and Design

The proposed system centers around the ESP32 microcontroller, which forms the core of the sensor node. The ESP32 is a low-cost, low-power device with built-in Wi-Fi and Bluetooth capabilities, making it well suited for IoT applications. A variety of environmental sensors are interfaced with the ESP32, including the DHT11 for monitoring temperature and humidity, the MQ-7 for detecting carbon monoxide gas, and the MQ-135 for sensing other harmful gases like ammonia, benzene and smoke. The sensor data is acquired by the ESP32 at regular intervals through its analog and digital input pins. The acquired environmental data is then transmitted wirelessly by the ESP32 over Wi-Fi to the ThingSpeak IoT cloud platform. ThingSpeak provides a user-friendly interface for data visualization, allowing the creation of customized dashboards and widgets to display the incoming sensor data in real time. The cloud-based architecture enables remote monitoring and control of the system from any internet-connected device, such as a smartphone, tablet, or computer. Additionally, ThingSpeak facilitates setting up alerts and notifications based on user-defined thresholds for the monitored environmental parameters, enabling timely interventions when necessary. The entire system is designed with a focus on low cost and low power consumption, making it suitable for various applications, including personal environmental monitoring, smart home automation and commercial deployments in sectors like agriculture, industrial process monitoring and smart city infrastructure. The open-source nature of the software components and the widespread availability of the hardware components contribute to the system's scalability and potential for further enhancements or integration with other IoT systems.

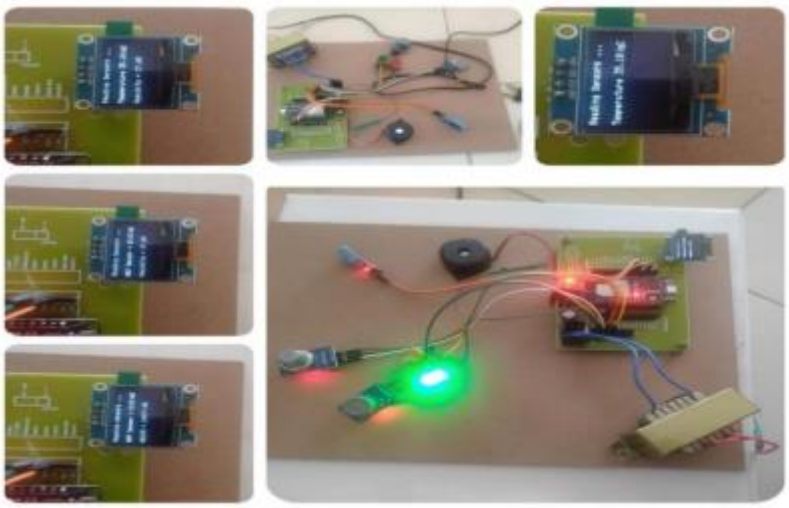

Fig 10: Implementation and Design

Conclusion

In conclusion, this project demonstrates the feasibility and potential of an Internet of Things based system for environmental monitoring using low-cost and readily available components. By leveraging the capabilities of the ESP32 microcontroller and the ThingSpeak cloud platform, the proposed solution enables real-time data collection, integration and visualization of various environmental parameters, such as air, temperature, humidity, air pressure and dust particulate concentration. The key strengths of this approach lie in its cost effectiveness, low power consumption, scalability and ease of implementation. The use of open-source software and hardware components further enhances the accessibility and potential for customization of the system, catering to a wide range of application scenarios.

Future Scope

The future scope of an IoT-based environmental monitoring system like the one proposed in this project is vast and multifaceted. As technology continues to evolve and the adoption of IoT solutions increases, several exciting possibilities emerge:

1. **Integration with advanced sensors:** The system's capabilities can be further expanded by incorporating additional sensors to monitor a wider range of environmental parameters, such as soil moisture, water quality, noise levels and greenhouse gas emissions. This would provide a more comprehensive understanding of environmental conditions and enable targeted interventions.
2. **Edge computing and data analytics:** By leveraging edge computing and advanced data analytics techniques, the system could provide real-time insights and predictive modeling capabilities. This would enable proactive decision-making and timely interventions to mitigate environmental issues before they escalate.
3. **Interoperability and ecosystem integration:** Developing standardized protocols and interfaces would allow seamless integration with other IoT systems, smart city initiatives and environmental monitoring networks. This interconnectivity would facilitate data sharing, collaborative efforts and a holistic approach to environmental management.

Recommendations

Based on the findings of this study, the following recommendations were made;

1. **Deployment in Sensitive Areas:** It is recommended that the developed monitoring system be deployed in environmentally sensitive or pollution-prone areas (e.g., industrial zones, urban centers or agricultural lands) for real-time tracking of environmental parameters.
2. **Integration with Cloud Platform:** The system should be integrated with robust cloud platforms (such as ThingSpeak, Blynk or Firebase) to enable long-term data storage, remote access and historical analysis.
3. **Scalability and Modularity:** Future designs should incorporate modular sensors that allow easy customization or expansion, depending on the specific environmental parameters required for a given application.
4. **Use of Renewable Energy Sources:** To enhance sustainability, it is recommended that the ESP32-based system be powered by solar or other renewable energy sources, especially in remote or off-grid locations.
5. **User-Friendly Interface:** The system should be paired with a mobile or web-based dashboard to allow users, including non-experts to easily interpret data and receive alerts when parameters exceed safe thresholds.
6. **Policy Adoption and Community Use:** Governments and environmental agencies should consider adopting such smart monitoring systems for environmental compliance and public safety. Educational institutions can also use them for research and teaching.
7. **Regular Calibration and Maintenance:** To ensure data accuracy and system reliability, periodic calibration of sensors and routine maintenance should be carried out.
8. **Incorporation of AI/ML for Prediction:** Incorporating artificial intelligence or machine learning algorithms can enhance the system's capability for trend analysis, forecasting and automated response to environmental changes.

References

Abdullah A.H., Sudin S, & Ajit M.I. (2018) Development of ESP32-based Wi-Fi Electronic Nose System for Monitoring LPG Leakage at Gas Cylinder Refurbish Plant. *International Conference on Computational Approach in Smart Systems Design and Applications,* DOI: 10.1109/ ICASSDA.2018.8477594.

Acevedo, M.F. (2016) "Real-Time Environmental Monitoring Sensors and Systems", Crc Press

Aghenta, L.O. & Iqbal, M.T. (2019). Low Cost, Open Source IoT-Based SCADA System Design Using Thinger.IO and ESP32 Thing. *Electronics,*DOI: 10.3390/electronics8080822.

Allafi, I. & Iqbal, T. (2017) Design and implementation of a low cost web server using ESP32 for real-time photovoltaic system monitoring. *2017 IEEE Electrical Power and Energy Conference,* DOI: 10.1109/EPEC.2017.8286184.

Babiuch, M., Foltynek, P &Smutny P. (2019) Using the ESP32 Microcontroller for Data Processing. *International Carpathian Control Conference,* DOI: 10.1109/ CarpathianCC.2019. 8765944.

Carducci, C.G.C., Monti, A.,& Schraven, M.H,(2019) Enabling ESP32 based IoT Applications in Building Automation Systems. *IEEE International Workshop on Metrology for Industry 4.0 and IoT, MetroInd 4.0 and IoT.* DOI: 10.1109/METROI4.2019.8792852.

Catelani, M, Ciani, L, & Bartolini, A., (2020). Characterization of a low-cost and low-power environmental monitoring system. *International Instrumentation and Measurement Technology Conference,* DOI: 10.1109/ I2MTC43012.2020.9129274.

Doorsamy, W., Paul, B. S. & Marwala, T. (2020). "The Disruptive Fourth Industrial Revolution: Technology, Society and Beyond", *Springer,* 6(8), 111- 131

Espressif Systems, "Esp32 Series Datasheet", Version 3.8, 2021

Goyal, D., Balamurugan, S., Peng, S. L. & Jat, D.S. (2019) "The IoT and the Next Revolutions Automating the World", *Igi Global,* Ch (10, 12)

Hanes, D.,Salguiero, G.,Grossetete, P.,Barton, R.,&Henry, J.(2017) "IoT Fundamentals: Networking Technologies, Protocols and Use Cases for the Internet of Things", *Cisco Press, E-Book Edition,*Ch(1-2).

Harmancioglu, N.B., Ozkul, S.D. & Fistikoglu, O. (2003). "Integrated Technologies for Environmental Monitoring and Information Production", *Paul Geerders Springer Science & Business Media,* 20(4), 7-13.

Hassan, Q. F. (2018) "Internet of Things A to Z: Technologies and Applications", *Ieee Press*, 7

Ibrahim, D., Ibrahim, A. (2017) "The Official Esp32 Book", *Elektor, E-Book Edition*, Pp 22-24

Kafli, N. & K. Isa. (2017) Internet of Things (IoT) for measuring and monitoring sensors data of water surface platform. *in 2017 IEEE 7th International Conference on Underwater System Technology: theory and applications (USYS).*

Kodali, R.K. & Valdas, A. (2018) MQTT Based Monitoring System for Urban Farmers Using ESP32 and Raspberry Pi. *International Conference on Green Computing and Internet of Things, ICGCIoT.* DOI: 10.1109/ ICGCIoT.2018.8752995.

Maier, A, Sharp, A. & Vagapov, Y. (2017) Comparative analysis and practical implementation of the ESP32 microcontroller module for the internet of things. *Internet Technologies and Applications,* DOI: 10.1109/ ITECHA.2017.8101926

Misal, S.R., Prajwal, S.R., &Niveditha, H.M.(2020) Indoor Positioning System (IPS) Using ESP32, MQTT and Bluetooth. *Fourth International Conference on Computing Methodologies and Communication,* DOI: 10.1109/ ICCMC48092.2020.ICCMC-00015.

Mishra, A, Reichherzer, T, & Kalaimannan, E,(2020) Trade-offs involved in the choice of cloud service configurations when building secure, scalable, and efficient Internet-of-Things networks. *International Journal Distribution Sensory Network,* DOI: 10.1177/1550147720908199.

Nikolov, N & Nakov, O. (2019) Research of Secure Communication of Esp32 IoT Embedded System to.NET Core Cloud Structure using MQTTS SSL/ TLS. *International Scientific Conference Electronics,* DOI: 10.1109/ ET.2019.8878636.

Niswar, M. (2018) IoT-based water quality monitoring system for soft-shell crabs farming. *In 2018 IEEE International Conference on Internet of Things and Intelligence System*

Park, J., K.T. Kim, & W.H. Lee, (2020) Recent Advances in Information and Communications Technology (ICT) and Sensor Technology for Monitoring Water Quality. *Water, 12*(2), 510-524

PopovicT. et al., (2017). "Architecting an IoT-Enabled Platform for Precision Agriculture and Ecological Monitoring: A Case Study", *Computers and Electronics in Agriculture,* 9(5), 255-265

Puliafito, A., Celesti, A, &Villari, M,(2015) Towards the integration between IoT and cloud computing: An approach for the secure self-configuration of embedded devices.*International Journal Distribution Sensory Network*, DOI: 10.1155/2015/286860.

Seneviratne, P. (2018). Hands-On Internet of Things with Blynk Build on the Power of Blynk to Configure Smart Devices and Build Exciting IoT Projects. *Packet Publishing*, Birmingham.

Serikul, P., Nakpong, N. & Nakjuatong, N. (2018) Smart Farm Monitoring via the BlynkIoT Platform: Case Study: Humidity Monitoring and Data Recording. *2018 16th International Conference on ICT and Knowledge Engineering, Bangkok, 21(23*), 70-75. https://doi.org/10.1109/ICTKE.2018.8612441

Shinde, V.R., Tasgaonkar, P.P. & Garg, R.D. (2018) Environment Monitoring System through Internet of Things (IOT). *2018 International Conference on Information, Communication, Engineering and Technology,* 29(31), 1-4. https://doi.org/10.1109/ICICET.2018.8533835

Rai, P. & Rehman, M. (2019) ESP32 Based Smart Surveillance System. *International Conference on Computing, Mathematics and Engineering Technologies,* DOI: 10.1109/ ICOMET.2019.8673463.

Tan, L., Shi, N., Yu, K., Aloqaily, M., & Jararweh, Y. (2021) "A Blockchain-Empowered Access Control Framework for Smart Devices in Green Internet of Things", *ACM Transactions on Internet Technology, 21(3),* 1-20,https://doi.org/10.1145/3433542.

Zhen, L., Bashir, A.K., Yu, K., Al-Otaibi, Y.D., Foh, C.H., &Xiao, P. (2020) "Energy-Efficient Random Access for LEO Satellite-Assisted 6G Internet of Remote Things", *IEEE Internet of Things Journal, doi: 10.1109*/JIOT.2020.3030856.