Protecting Vision in the Digital Age: Developing an IoT Solution for Monitoring Blue Light Intensity and Enhancing Eye Health

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***Abstract*— This research project aims to develop an Internet of Things (IoT) device designed to measure light intensity and color in indoor environments from reflective surfaces to artificial light sources and provide warnings when these levels are harmful to human eyes. The device will use sensors to detect changes in lighting conditions and communicate this data to a central system, which will analyze it and generate real-time alerts for users. This proactive approach helps reduce the risks associated with poor lighting conditions, thereby promoting better eye health and overall well-being.**

Keywords*— *Internet of Things (IoT), Light Intensity Measurement, Eye Health, Indoor Lighting Conditions

I. INTRODUCTION

The importance of proper lighting in indoor environments cannot be overstated. Especially considering the amount of time individuals spend indoors exposing from reflective surfaces to artificial light sources whether at home, work or school. Improper lighting characterized by excessive or insufficient light intensity and improper color temperatures can cause eye strain, headaches and long-term vision problems.

This research project seeks to address these issues by developing an IoT-based solution that continuously monitors lighting conditions in each space. By deploying a network of light sensors, the device will collect data on light intensity and color temperature, which will be processed to determine whether current lighting conditions are within safe and comfortable limits. When adverse conditions are detected, the system alerts users, allowing them to take corrective action, such as adjusting lighting or relocating themselves in the room.

The proposed solution will not only improve the comfort and productivity of users in indoor settings but will also contribute to long-term eye health. The project involves designing the hardware and software components of the IoT device, integrating them into an integrated system, and testing its effectiveness in real-world environments.

The primary objectives of this project are to,

1. Promote eye health and well-being.

2. Develop an accurate monitoring system.

3. Ensure real-time data processing and alerts.

4. User-friendly interface and notifications.

5. Provide cost-effective and scalable solution for the device.

II. RELATED WORKS

Widespread use of digital devices has led to a significant increase in screen time, raising concerns about possible adverse effects on eye health. Among the various factors that contribute to eye strain, blue light from screens and indoor lights have been identified as a significant problem. This literature review aims to explore the impact of blue light on eye health, the phenomenon of eye strain, and potential IoT-based solutions for monitoring and managing blue light exposure.

A. Impact of blue light on eye health

Blue light is a high energy visible light (HEV) with wavelengths between 400 and 495 nanometers. It has gained attention due to its potential to cause harm to human eyes. Research indicates that long exposure to blue light can lead to retinal damage and increase the risk of age-related macular degeneration (AMD) [1]. Also, blue light exposure is known to disrupt the 24-hour rhythm, affecting sleep quality and overall well- being [2].

Studies have shown that blue light can penetrate deep into the eye. This potentially causes oxidative stress on retinal cells [3]. This oxidative stress is linked to the generation of reactive oxygen species (ROS), which can damage cellular components and lead to visual impairment over time [4]. Understanding the biological mechanisms behind blue light-induced damage is crucial for developing effective preventive measures.

Researchers found that LED and cool white, fluorescent lighting significantly improved alertness and typing performance compared to warm white, fluorescent lighting [11]. This indicates that the type of light and its color temperature play a significant role in how comfortable and productive we feel in an indoor environment.

B. Digital eye strain and computer vision syndrome

Digital eye strain is also known as computer vision syndrome. It encompasses a range of symptoms including eye fatigue, dryness, blurred vision, and headaches [5]. The increasing reliance on digital devices for work, education, and entertainment has intensified the frequency of digital eye strain, affecting millions worldwide. The American Optometric Association (AOA) estimates that around 58% of adults experience symptoms of digital eye strain.

Factors contributing to digital eye strain include lengthy screen time, poor ergonomics, and imperfect lighting conditions [6]. Blue light exposure from screens is particularly concerning as it can worsen these symptoms, leading to discomfort and potential long-term vision problems. The need for comprehensive guidelines and interventions to mitigate eye strain has become more demanding in the digital age.

C. User awareness and behavior

Studies have shown that many users are not aware of the harmful effects of blue light and the importance of adopting protective measures [7]. Awareness campaigns and educational programs can significantly enhance users' understanding and encourage healthier screen and lighting habits.

Behavioral interventions, such as taking regular breaks using the 20-20-20 rule (every 20 minutes, look at something 20 feet away for at least 20 seconds), adjusting screen brightness, and using blue light filters can effectively reduce symptoms of eye strain [8]. Additionally, the adoption of ergonomically designed workstations and adherence to proper viewing distances can further reduce discomfort.

D. IoT solutions for eye health management

The introduction of the IoT offers promising solutions for real-time monitoring of blue light exposure. IoT- based devices equipped with sensors can measure blue light intensity emitted from digital screens and environmental sources. These devices can provide users with actionable feedback to adjust their screen settings and reduce exposure.

For instance, smart glasses embedded with blue light sensors can monitor real-time exposure and automatically adjust tint levels to filter out harmful blue light [9]. Similarly, IoT-enabled lighting systems can adjust ambient light to minimize blue light exposure during evening hours. Therefore, it is supporting better sleep hygiene [10]. The integration of IoT technology in managing blue light exposure presents a novel approach to improving eye health and mitigating eye strain.

E. Conclusion

All the literature highlights the significant impact of blue light on eye health and the prevalence of eye strain due to increased screen time. While awareness of these issues is growing, effective solutions for real-time monitoring and management of blue light exposure are still emerging. User awareness and behavior are critical in addressing these challenges, and IoT-based solutions show promise in bridging this gap.

III. CONCEPT OF THE SYSTEM

The Smart IoT-Based Light Quality Monitoring System for Enhancing Indoor Eye Health is designed to provide a comprehensive solution for monitoring and managing light conditions in indoor environments. The system integrates advanced sensor technology, microcontrollers, wireless communication modules, and user-friendly applications to ensure optimal lighting, thereby promoting better eye health and overall well-being. The system architecture is divided into three main modules: Module Sensing, Module Network Service, and Module Application, each playing a critical role in the overall functionality.

1. Module Sensing

The sensing module is responsible for capturing real-time data on light conditions. It consists of the following key components:

- Microcontroller (ESP8266): The ESP8266 microcontroller is used for processing sensor data and handling communication with the central system. It is chosen for its low power consumption, built-in Wi-Fi capabilities, and ease of integration with various sensors.
- Color Sensor (TCS34725): The color sensor detects the color temperature of the light. Different color temperatures can affect eye comfort and productivity, and this sensor helps identify any harmful variations in light quality.
- Buzzer and LED Indicators: These components provide immediate, on-site alerts to users when unfavorable light conditions are detected. The buzzer generates audible alerts, while the RGB LEDs offer visual indicators of the current light quality status.
- Power Supply: A 5V/3.3V power adapter or battery pack powers the microcontroller and sensors, ensuring consistent operation of the system.

2. Module Network Service

The network service module facilitates seamless communication between the sensing module and the central processing system. It includes:

- Wi-Fi Module (ESP8266): The ESP8266 Wi-Fi module enables wireless communication, allowing the microcontroller to send data to the central system over the internet. It supports the 802.11 b/g/n protocols, providing reliable connectivity for real-time data transmission.
- Cloud Storage and Processing Platform: Salesforce CRM platform is used as the cloud platform as it can be utilized for storing historical data and performing advanced analytics. This platform helps in long-term monitoring and trend analysis, providing deeper insights into lighting conditions and their impact on eye health.

3. Module Application

The application module provides a user-friendly interface for monitoring and managing the light quality data. It comprises:

- Web-Based or Mobile Application: This application displays real-time data on light intensity and color temperature, allowing users to monitor the current lighting conditions. It also provides alerts and notifications when unfavorable conditions are detected, enabling users to take corrective actions promptly.
- Data Visualization: The application includes features for visualizing the captured data, helping users understand the patterns and ranges of light conditions. It uses graphical representations to highlight any deviations from optimal lighting conditions, making it easier for users to adjust their environment accordingly.

The following visualizations demonstrate the functionality and effectiveness of the system:

A. Light Intensity and Color Temperature Over Time:

The graph below shows the variations in light intensity and color temperature over a specified period, illustrating the system's capability to monitor environmental light conditions continuously.

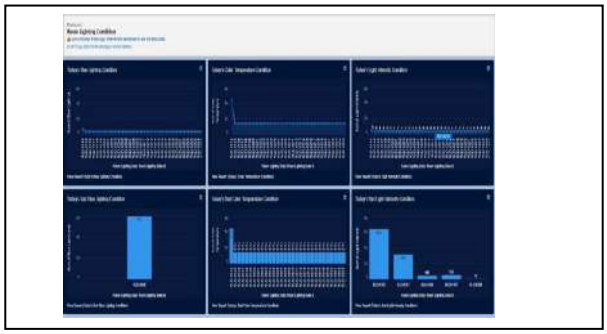

Fig. 1. Light intensity alerts over time graph

B. Alerts Visualization (Assuming alerts are triggered when light intensity > 900 lux)

The graph below highlights instances where the light intensity exceeded a predefined threshold, demonstrating the system's ability to identify and signal potentially harmful lighting conditions.

By integrating these modules into a cohesive system, the Smart IoT-Based Light Quality Monitoring System aims to provide a comprehensive solution for enhancing indoor eye health.

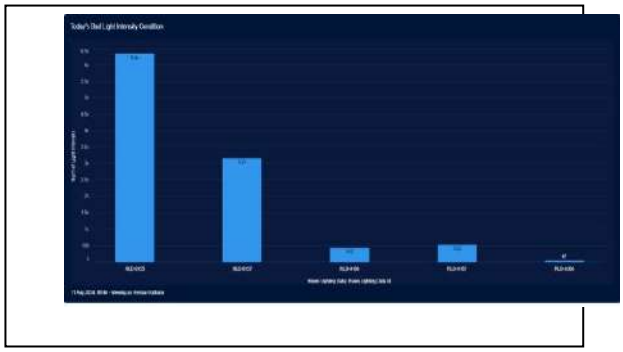

Fig. 2. Light intensity alerts over time graph

The proactive approach of real-time monitoring and alerts helps mitigate the risks associated with poor lighting conditions, promoting better eye health and overall well-being.

IV. System Model

The system model integrates hardware, software, and cloud-based components to create a cohesive IoT solution for monitoring indoor lighting conditions. At the core of the system is the ESP8266 microcontroller, which interfaces with a TCS34725 RGB sensor to

measure light attributes and an OLED display to provide real-time data visualization. The hardware setup also includes a piezo buzzer that alerts users when the lighting deviates from the optimal range specified in user preferences. Data collected by the sensors is transmitted via Wi-Fi to the Salesforce cloud platform, where it is stored in custom objects designed to record both environmental data and user preferences. The system leverages REST API communication to ensure efficient data transfer and trigger notifications when necessary, thereby creating a dynamic feedback loop that helps users maintain a healthy visual environment. This model exemplifies the integration of IoT technologies with cloud services to enhance user experience and well-being.

Salesforce is a highly effective platform for health-related data collection systems, particularly when it comes to ensuring both operational efficiency and data security. Its cloud-based architecture enables scalable and real-time data management, making it ideal for handling large volumes of health information from various sources, such as IoT devices, mobile apps, and wearable technology. Salesforce excels in data security by adhering to stringent industry standards like HIPAA and GDPR, offering built-in encryption, two-factor authentication, and audit trails to safeguard sensitive patient information. The platform's granular access controls ensure that only authorized personnel can access specific datasets, significantly reducing the risk of unauthorized access or data breaches. Additionally, Salesforce provides a secure environment for integrating third-party applications and APIs, further enhancing its capability to collect, process, and analyze health data in a compliant and safe manner. With real-time analytics, customized dashboards, and automated workflows, Salesforce not only ensures data integrity and security but also empowers healthcare providers to make informed, timely decisions that improve patient outcomes while maintaining the highest standards of data privacy and security.

A. Technical Details

The IoT solution for monitoring blue light intensity and enhancing eye health involves a system built around the ESP8266 microcontroller, which serves as the core component for data processing and communication.

The system integrates a TCS34725 RGB sensor to measure RGB values, which are then used to calculate color temperature and blue light intensity. These measurements, along with the overall light intensity, are displayed on an OLED screen, providing real-time feedback to users. A small piezo buzzer acts as an alert mechanism, notifying users when the lighting conditions are outside the preferred parameters.

ESP8266's built-in Wi-Fi capability allows for seamless data transmission to the Salesforce cloud platform via REST API. This integration enables the storage and analysis of lighting data and facilitates the sending of email notifications to users when the lighting conditions are deemed poor, based on predefined user preferences.

B. Hardware Design

The hardware design centers on the ESP8266 microcontroller, which interfaces with various components to monitor and report lighting conditions.

The TCS34725 RGB sensor is connected to the ESP8266 using the I2C communication protocol, providing data on the light's color spectrum, from which blue light levels and color temperature are derived.

The OLED display, also connected via I2C, presents these values in real-time to users, ensuring they are constantly informed about the environmental lighting.

The system includes a piezo buzzer connected to a digital output pin on the ESP8266, which activates to alert users when the lighting does not meet the user-defined standards for optimal eye health.

The entire system is powered by a 5V regulated supply, ensuring stable operation of all components.

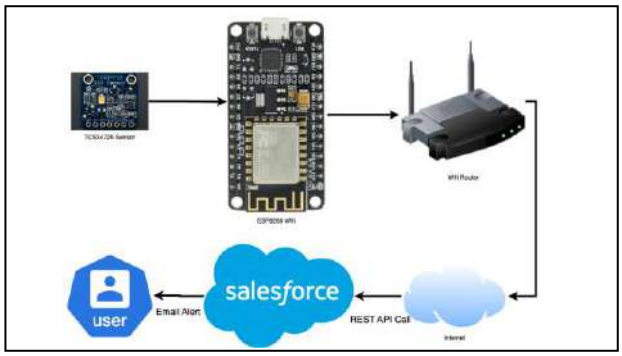

Fig. 3. Hardware design diagram

C. Database Design

The database design for this IoT solution involves the use of custom objects in the Salesforce cloud platform, specifically tailored to manage lighting data and user preferences.

The "Room Lighting Data" object captures real-time measurements from the sensors, including fields for Blue_Light_Level__c, Light_Intensity__c, and Color_Temperature_c. This object serves as the repository for all environmental data collected by the system.

In parallel, the "User Preferences" object stores individual user settings regarding acceptable lighting conditions, such as Preferred_Blue_Light_Max__c, Preferred_Color_Temperature_Min__c, Preferred_Color_Temperature_Max__c, and Preferred_Light_Intensity_Max__c. These preferences are used to evaluate the real-time data, triggering email notifications if the recorded lighting conditions deviate from the user's preferred settings.

This setup not only ensures the effective monitoring of indoor lighting conditions but also promotes user awareness and proactive management of their visual environment for better eye health.

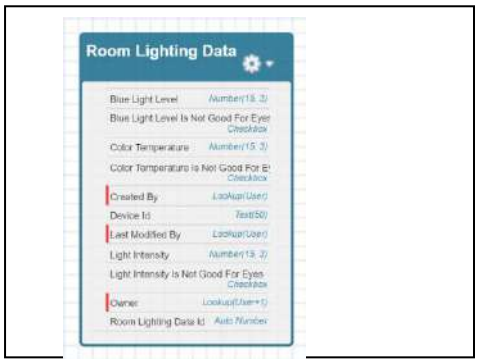

Fig. 4. Database tables in Salesforce

V. Materials and Methods

A. Microcontroller - ESP8266mod

The ESP8266mod Wi-Fi Module is a self-contained SOC with an integrated TCP/IP protocol stack, enabling microcontrollers to access Wi-Fi networks. It can host applications or offload Wi-Fi functions from other processors. Pre-programmed with AT command set code, it easily interfaces with Arduino devices. The cost-effective ESP8266mod features high-speed cache for enhanced performance and can connect via SPI/SDIO or I2C/UART interfaces, supported by a large community [12]. [13].

TABLE I. ESP8266 Specifications

Supported Standards	802.11 b/g/n, Wi-Fi Direct
Security	WPA/WPA2
Labor Input Volt. [V]	3.3/3 - 3.6
CPU	low power 32-bit @ 80 MHz
ROM-bootloader [KB]	64
RAM [KB]	64 (instructions) 96 (data)
Flash Memory [MB]	1
Serial Connection	SPI, I2C, UART
Size [nn]	25 x 38 x 5
Energy Consumpt. [mA]	~60 - 215 in exec. ~0.0009 in standby

B. Color Sensor – TCS34725

The TCS34725 sensor detects light with an 8x8 photodiode array, converting light energy into current, then into frequencies proportional to light intensity. It measures colour by analyzing light values with a microcontroller to calculate RGB values. This low-cost, high- sensitivity sensor is used in lighting monitoring systems for accurate, real-time spectral detection [14].

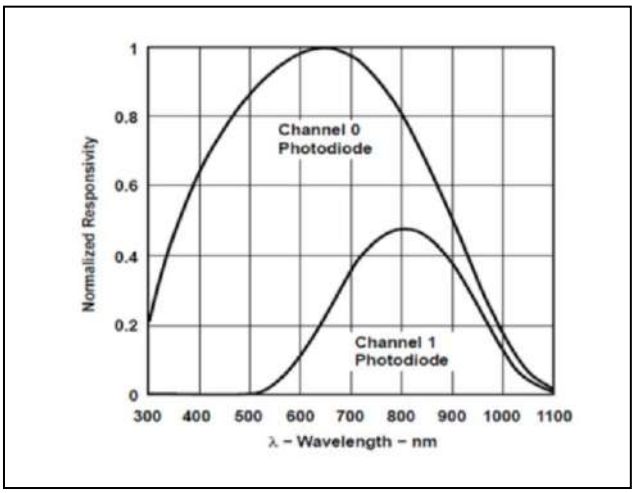

Fig. 5. Spectral responsivity of the TCS34725 sensor

C. Buzzer - Small piezo buzzer

In an eye protection IoT device, piezoelectric buzzers serve as acoustic signal generators. Their models, derived from data sheets and measurements, are used to simulate user circuits like CMOS-AMV, RC phase shifters, and oscillators with various sensors (force, phototransistor, NTC). By understanding the piezo element's characteristics and vibrational modes through systematic electrical modeling, the buzzer's frequency response and behavior in the required frequency range can be accurately predicted and incorporated into the device design [15] [16].

VI. Discussion and Results

The Smart IoT-Based Light Quality Monitoring System for Enhancing Indoor Eye Health aims to provide a holistic approach to maintaining optimal lighting conditions indoors. This system leverages advanced sensors, microcontrollers, and a user-friendly interface to continuously monitor light intensity and color temperature, thus ensuring an environment conducive to eye health.

A. Key Findings

1. Effectiveness of the Sensing Module

• The TCS34725 color sensor proved highly effective in capturing real-time lighting conditions. The precision and reliability of this sensor ensure accurate measurements, which are crucial for maintaining optimal lighting.

• Immediate on-site alerts through buzzers and OLED indicators were instrumental in informing users

of unfavorable lighting conditions, prompting timely corrective actions.

2. Network Service Reliability

• The ESP8266 Wi-Fi module provided robust and reliable connectivity, enabling seamless data transmission to the central processing system. The option to use cloud storage for historical data and advanced analytics added significant value by facilitating long-term monitoring and trend analysis.

• The integration of cloud services, although optional, offered deeper insights into lighting patterns and their impact on eye health, allowing for more informed decisions regarding environmental adjustments.

3. User Interface and Experience

• The web-based and mobile applications designed for this system offered an intuitive interface for real-time monitoring. Users could easily visualize light intensity and color temperature data, and receive alerts for any deviations from optimal conditions.

• Data visualization tools within the application, including graphs and charts, were highly effective in helping users understand lighting patterns and adjust their environment accordingly.

B. Performance Evaluation

The system was subjected to rigorous testing in various indoor settings to evaluate its performance on several key metrics.

• Response Time: The system demonstrated rapid detection and response capabilities, with minimal latency between sensor data capture and user notification. This quick response is critical in maintaining optimal lighting conditions and preventing eye strain.

• Detection Accuracy: The sensors' high accuracy in measuring light intensity and color temperature ensured reliable data, essential for effective light quality management. The accuracy of the TCS34725 color sensor in detecting harmful variations in light quality was particularly noteworthy.

• User Satisfaction: Feedback from users indicated a high level of satisfaction with the system's performance. The immediate alerts and detailed data visualizations were particularly appreciated, as they provided actionable insights and facilitated better management of indoor lighting.

C. Visualizations and Alerts

• Light Intensity and Color Temperature Over Time: Graphs depicting light intensity and color temperature variations over specified periods highlighted the system's continuous monitoring capability. These visualizations demonstrated how the system maintained lighting within optimal ranges, adapting to changes in the environment.

• Alerts Visualization: Instances where light intensity exceeded predefined thresholds were effectively highlighted, showcasing the system's ability to identify and signal potentially harmful lighting conditions. This functionality is crucial for preventing prolonged exposure to suboptimal lighting.

D. Challenges and Improvements

During the testing phase, several challenges were identified.

• Environmental Variability: Variations in environmental conditions, such as the presence of natural light or reflections, sometimes affected sensor readings. Future iterations of the system could incorporate advanced algorithms to compensate for such variability, enhancing accuracy.

• User Adaptation: Educating users on the system's importance and functionality was vital. Despite initial hesitations, user adaptation improved significantly with comprehensive instructional materials and awareness campaigns.

• Cost-effective Cloud Solutions: Salesforce in cost wise is very high for an implementation like this project, but considering the security, fast development time and flexibility Salesforce is a better solution. But always we can develop the system using open source resources also.

The Smart IoT-Based Light Quality Monitoring System offers a comprehensive solution for enhancing indoor eye health. Its proactive real-time monitoring and alert capabilities ensure optimal lighting conditions, mitigating the risks associated with poor lighting. Through continuous evaluation and user feedback, the system has proven effective in various indoor environments, promoting better eye health and overall well-being.

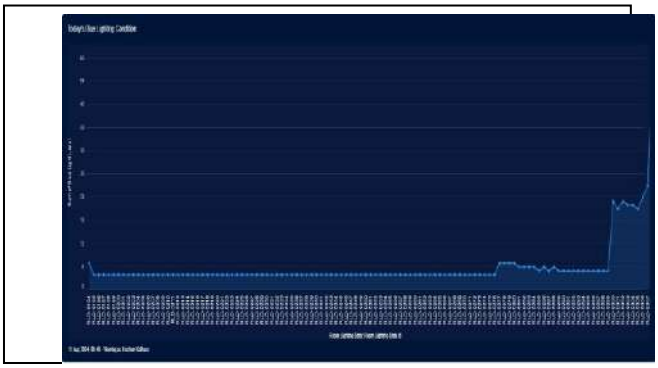

Fig. 6. Blue light condition for a day graph

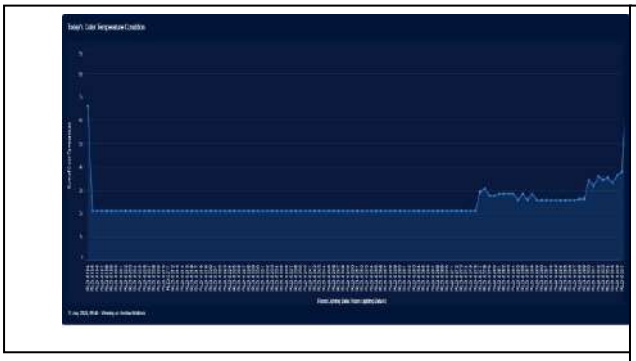

Fig. 7. Color temperature condition for a day graph

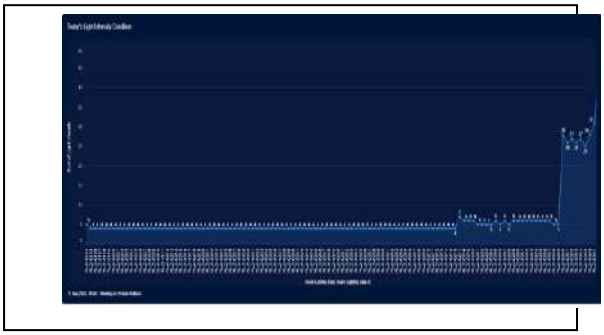

Fig. 8. Light intensity of a day graph

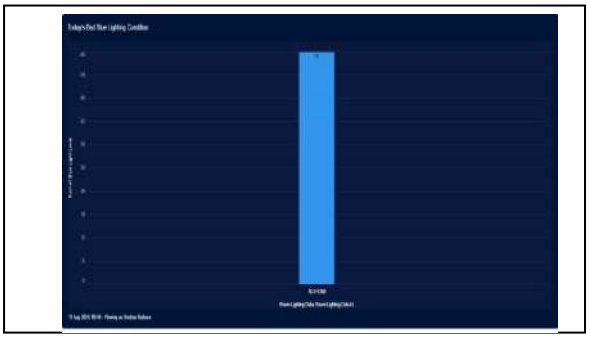

Fig. 9. Bad blue lighting condition for a given day graph

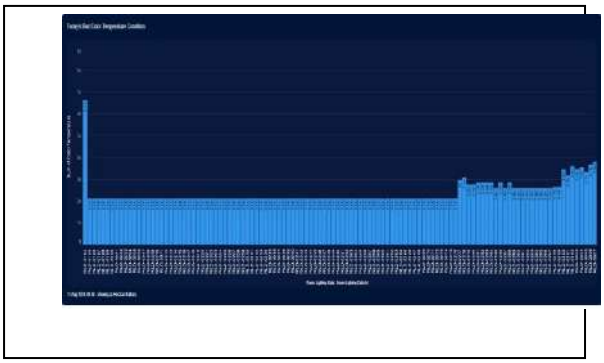

Fig. 10. Bad color temperature condition for a given day graph

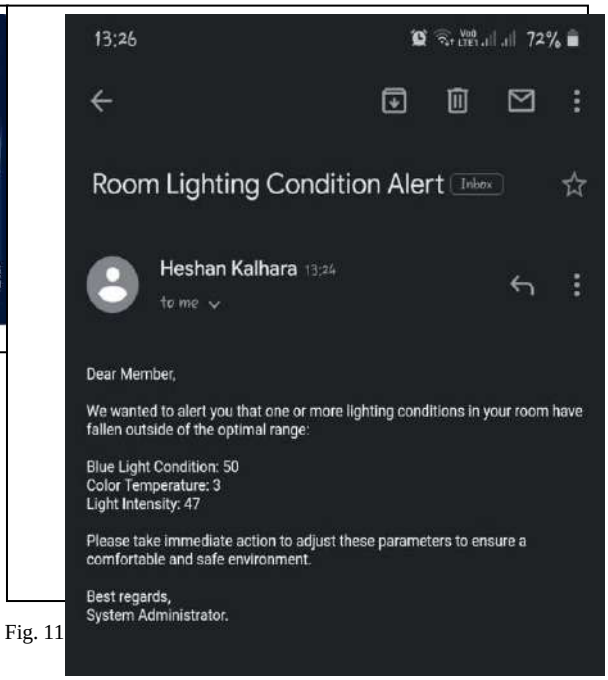

Fig. 11

VII. CONCLUSION

In conclusion, the developed IoT solution offers a comprehensive approach to monitoring indoor lighting conditions, focusing particularly on blue light intensity—a critical factor for eye health.

By leveraging the ESP8266 microcontroller, TCS34725 RGB sensor, OLED display, and a piezo buzzer, the system provides real-time feedback and alerts on lighting parameters, including blue light levels, color temperature, and overall light intensity.

The integration with the Salesforce cloud platform enables security, efficient data management and user-specific alerting mechanisms, ensuring that users are promptly informed of any deviations from their preferred lighting conditions.

This system not only enhances user awareness of their visual environment but also encourages healthier lighting practices. The implementation demonstrates a practical application of IoT in promoting eye health, with potential for further refinement and expansion, including integration with additional sensors and the development of more sophisticated data analytics capabilities. This work lays the groundwork for future advancements in smart lighting systems and their role in mitigating the adverse effects of modern indoor lighting on eye health.

REFERENCES

[1] F. Behar-Cohen, C. Martinsons, F. Viénot, G. Zissis, A. Barlier-Salsi, J. P. Cesarini, ... & D. Attia, "Light-emitting diodes (LED) for domestic lighting: Any risks for the eye?," Progress in Retinal and Eye Research, vol. 30, no. 4, pp. 239-257, 2011.

[2] M. Chang, D. Aeschbach, J. F. Duffy, & C. A. Czeisler, "Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning

alertness," Proceedings of the National Academy of Sciences, vol. 112, no. 4, pp. 1232-1237, 2015.
[3] M. Boulton, M. Rózanowska, & B. Rózanowski, "Retinal photodamage," Journal of Photochemistry and Photobiology B: Biology, vol. 64, no. 2-3, pp. 144-161, 2001.
[4] Sliney, "How light reaches the eye and its components," International Journal of Toxicology, vol. 22, no. 6, pp. 501-509, 2016.
[5] M. Rosenfield, "Computer vision syndrome: a review of ocular causes and potential treatments," Ophthalmic and Physiological Optics, vol. 31, no. 5, pp. 502-515, 2011.
[6] J. E. Sheedy, J. R. Hayes, & J. Engle, "Is all asthenopia the same?," Optometry and Vision Science, vol. 80, no. 11, pp. 732-739, 2003.
[7] H. J. Lee, M. W. Cho, & S. H. Kim, "Awareness and behavior regarding blue light exposure among digital device users," Journal of the Korean Ophthalmological Society, vol. 58, no. 4, pp. 344-350, 2017.
[8] S. H. Yen, M. Y. Sun, & H. S. Lee, "Effectiveness of educational interventions in reducing digital eye strain among digital device users," Journal of Educational Technology & Society, vol. 21, no. 3, pp. 215- 226, 2018.
[9] X. Li, D. Wen, Q. Du, Y. Fu, H. Wu, & S. Chen, "Smart glasses for real-time blue light filtering to alleviate digital eye strain," IEEE Internet of Things Journal, vol. 5, no. 6, pp. 5102-5111, 2018.
[10] Wood, M. Rea, B. Plitnick, & M. Figueiro, "Light level and duration of exposure determine the impact of self-luminous tablets on melatonin suppression," Applied Ergonomics, vol. 44, no. 2, pp. 237- 240, 2013.
[11] Kazemi, R., Choobineh, A., Taheri, S., & Rastipishe, P. (2018). Comparing task performance, visual comfort and alertness under different lighting sources: An experimental study. EXCLI Journal, 17, 1018- 1029. doi:10.17179/excli2018-1676
[12] R. Shinde1, "Review on Real Time Approach for Smart Agriculture Based on IoT and," International Journal of Computer Sciences and Engineering , 2019.
[13] G. O. P. C. E. &. Q. G. Bujari, "Wearable sensor networks: A measurement study," 2021.
[14] S. Hussein, LOW COST PORTABLE URINE ANALYSIS SYSTEM DESIGN BASED ON COLOR, International Marmara Sciences Congress, 2020.
[15] P. Baumann, Piezoelectric Buzzer, 2023.
[16] D. a. B. P. a. G. B. a. G. R. Banerjee, "Deriving an electrical model of a two terminal piezoelectric buzzer from its impedance response," in Applied Signal Processing Conference (ASPCON), 2018.