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IoT Based Light Intensity Measurement Devices for Indoor Monitoring

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Abstract

This work focuses on enhancing workplace lighting conditions and occupational safety by leveraging IoT technology. Integrating an IoT system with a prototype luxmeter circuit, efficiently measures light intensity. The use of an LDR sensor detects light presence and absence, while the ESP32 serves as a cost-effective and low-power microcontroller with integrated Wi-Fi capabilities. The ESP32 facilitates data transmission to the Blynk application, allowing real-time monitoring of light intensity in lumen units. The developed method consistently provides accurate measurements, with average percentage differences ranging from 12.31% to 33.61% compared to traditional lux meters. This innovative approach holds promise for ensuring optimal lighting conditions, influencing factors like performance and safety in occupational environments.

1. Introduction

In the contemporary era, electrical power holds paramount importance, especially with the rapid advancement of technology. Adequate lighting is crucial in various settings such as hospitals, laboratories, and schools (Cocking, 2022), not only for safety but also to enhance productivity, health, and overall well-being. Insufficient lighting can adversely affect focus, and efficiency, and even pose risks of accidents. In healthcare facilities, lighting plays a vital role in staff performance and patient recovery. The recommended lighting levels vary across different areas, ranging from nursing stations to patient rooms, and even neonatal intensive care units (NICUs) (Susilaningsih et al, 2019). Proper lighting in these settings contributes to maintaining a comfortable environment and aids in medical tasks and patient care. Laboratories also demand precise lighting to ensure accuracy in experiments and prevent contamination (Idkhan et al, 2019). Cleanrooms require adherence to strict lighting standards to maintain sterility. The lighting design must align with cleanliness standards and the specific tasks carried out in the laboratory, emphasizing the importance of proper illumination. Similarly, schools and classrooms require sufficient lighting to create a conducive learning environment. Adequate light intensity, ranging from 250 to 300 lux (Susilaningsih et al, 2019), contributes to students' safety and better concentration, fostering an atmosphere conducive to learning (Watini et al, 2022). Despite the importance of accurate light measurement, traditional lux meters can be expensive (Anonymous, 2022). Additionally, smartphone applications often fail to provide precise readings due to the proximity of the device output to the sensor, requiring users to hold the device close and potentially introducing errors (Finio, 2019). This work addresses these challenges by developing a user-friendly and cost-effective prototype using IoT technology. The objectives of the work include designing a prototype capable of accurately measuring light intensity through IoT and transmitting data to the Blynk application for remote monitoring. The aim is to evaluate the prototype's efficiency with minimal error rates.

2. Methodology

The overall block diagram of the system is shown in Fig. 1. The LDR sensor must detect the presence of light and measure the light intensity. The ESP32 is a microcontroller that used to control the whole system and must be connected to the battery to function. An ESP32 get information through the Blynk application for monitoring the output during the measurement. The buzzer will be beeping if the ESP32 does not measure the data and send it to the Blynk application. As a result, this system enables users to monitor the data.

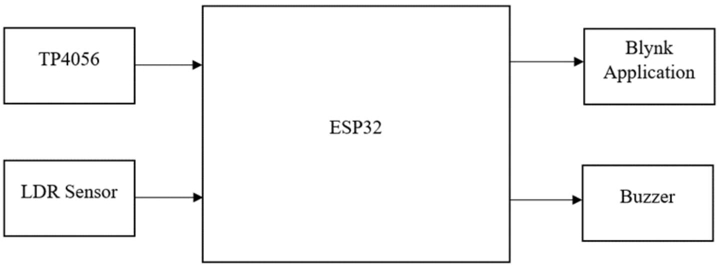


Fig. 1 *Block diagram of the system*

This system employs an ESP32 microprocessor, powered by a battery, to manage the setup. An LDR sensor detects light presence. The ESP32, with integrated Wi-Fi, transmits data to the Blynk app for real-time monitoring in lumen units. The flowchart, illustrated in Fig. 2.

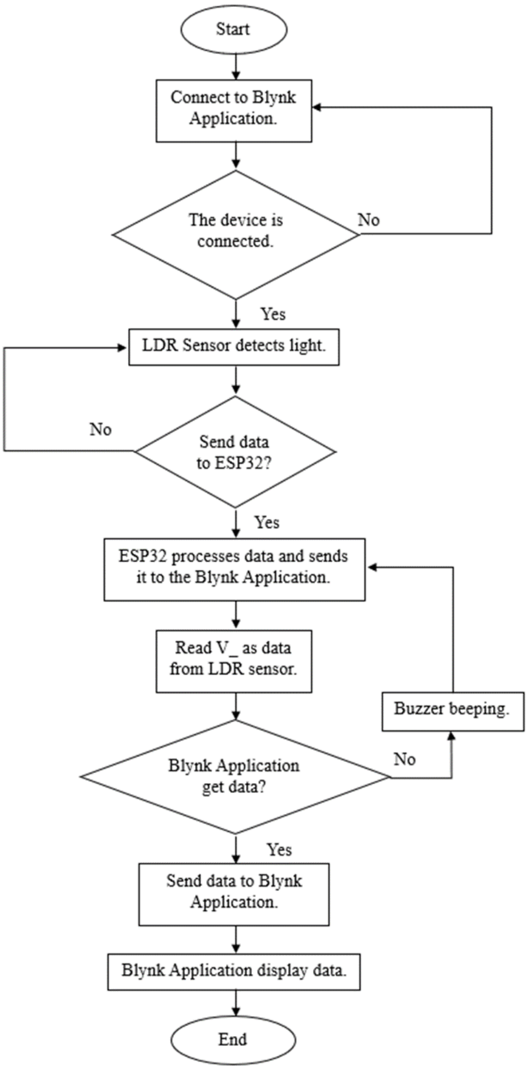


Fig. 2 *Flowchart of the system*

3. Results and Discussion

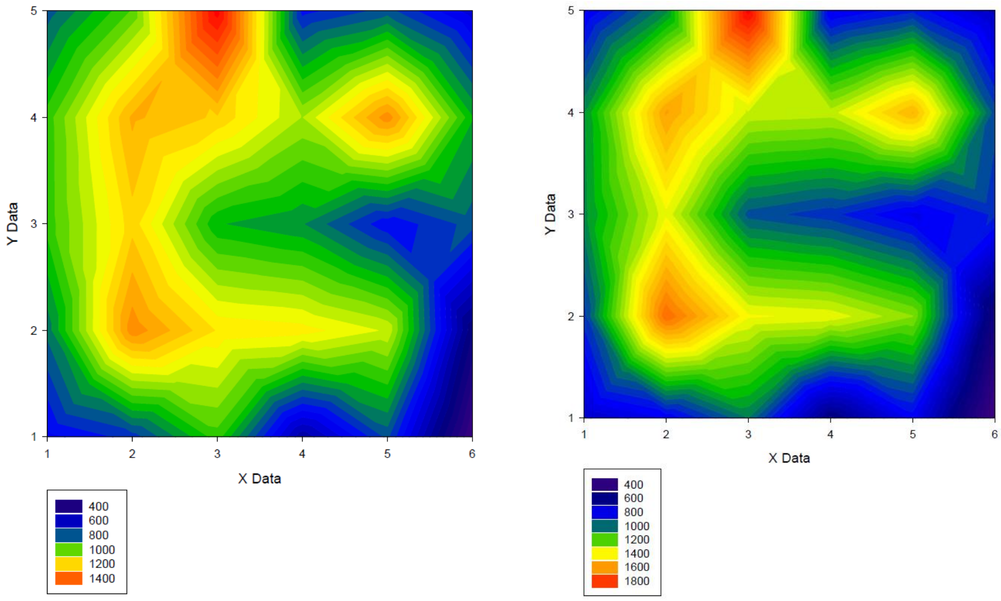
The conventional Lux meter and prototype reading were done for all four rooms. Each room is divided into several points based on how many lamps are in the room. The data from the lux meter will be compared to the prototype.

3.1 Room 1: Medical Engineering Laboratory

For Room 1: Medical Engineering Laboratory there are 30 points of lamp with area of 11m × 16m in this room. Fig. 3 shows the layout of Room 1: Medical Engineering Laboratory. The division of points for horizontal was 6 points which is A, B, C, D, E and F and for the vertical division is 5 points. The point will be written as A1 until F5 based on the point location in the room.

Fig. 3 *Layout of Room 1: Medical Engineering Laboratory*

Fig. 4 presents an illuminance contour for Room 1: Medical Engineering Laboratory, depicting Lux Meter and Prototype data. The contour reveals varied lux values through a color spectrum, with some points displaying a blue spectrum indicative of lux levels below 400 lux. This dip is attributed to broken lamps in specific areas, disrupting light distribution and reducing overall lux levels. Consequently, the room falls below the Malaysian standard of 500 lux for proofreading. The impact underscores the importance of regular maintenance and prompt replacement of malfunctioning light sources in achieving optimal lighting conditions. Addressing broken lamps not only ensures compliance with standards but also enhances visibility and safety in the laboratory, supporting precision in tasks like research and medical device testing.



(a) (b)

Fig. 4 *Illuminance contour from (a) Lux meter and (b) Prototype for Room 1: Medical Engineering Laboratory*

Table 1 shows the comparison between the Lux Meter and Prototype for Room 1: Medical Engineering Laboratory based on the location of the lamp point. The data that has been measured from the lux meter and prototype has been placed in this table. After that, the analysis of the comparison of percentage differences will be described.

Table 1 *Comparison of luminescence for Room 1: Medical Engineering Laboratory*

Point, *N*	Lux Meter, lx	Prototype, lx
A1	776	791
A2	936	1031
A3	934	1022
A4	812	899
A5	665	712
B1	964	1024
B2	1248	1565
B3	1183	1349
B4	1307	1677
B5	736	801
C1	1541	1899
C2	1192	1311
C3	883	941
C4	1155	1366
C5	940	998
D1	702	787
D2	1037	1298
D3	842	892
D4	1137	1346
D5	526	545
E1	776	867
E2	1305	1523
E3	687	788
E5	770	814
F1	616	698
F2	882	935
F3	776	887
F4	445	496
F5	270	292
Total Average, x_i	903.87	1000.23
Mean, μ	30.129	33.341
Variance, σ^2	116.2569	123.9664
Standard Deviation, σ	10.777	11.138

The average Lux values for Lux Meter and Prototype were calculated from Table 1, resulting in means of 903.87 lx and 1000.23 lx, respectively, with standard deviations of approximately 10.777 lx and 11.138 lx. Despite exceeding the Malaysian Standard (MS) recommendation of 500 lux for proofreading, the average Lux values in the laboratory exhibit a reasonable proximity, with a low average percentage difference of 12.31% between Lux Meter and Prototype readings. While variations exist, they are relatively small, indicating consistency in Lux measurements. The higher Lux values, though surpassing MS guidelines, enhance visibility in the laboratory, crucial for precision tasks such as device fabrication and biological testing. The improved visibility reduces the risk of errors, facilitating accurate and efficient work for medical engineering students engaged in experiments and instrumentation tasks.

3.2 Room 2: Mechatronic Engineering Laboratory

For Room 2: Mechatronic Engineering Laboratory there are 13 points of lamp with area of 14m × 9m in this room. Fig. 5 shows the layout of Room 2: Mechatronic Engineering Laboratory. The division of points for horizontal was 3 points which is A, B and C and for the vertical division is 5 points. The point will be written as A1 until C3 based on the point location in the room.

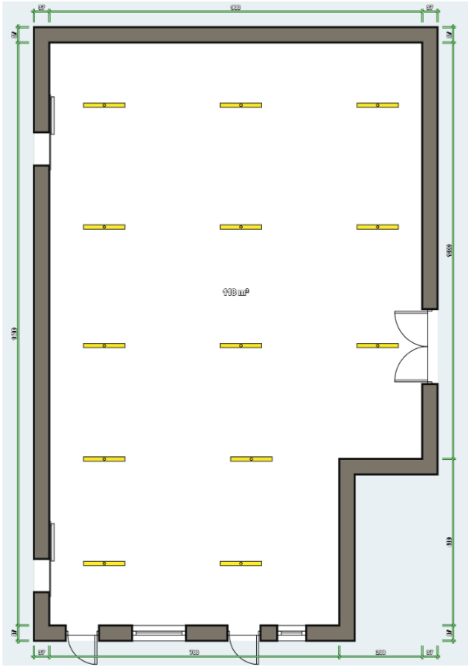


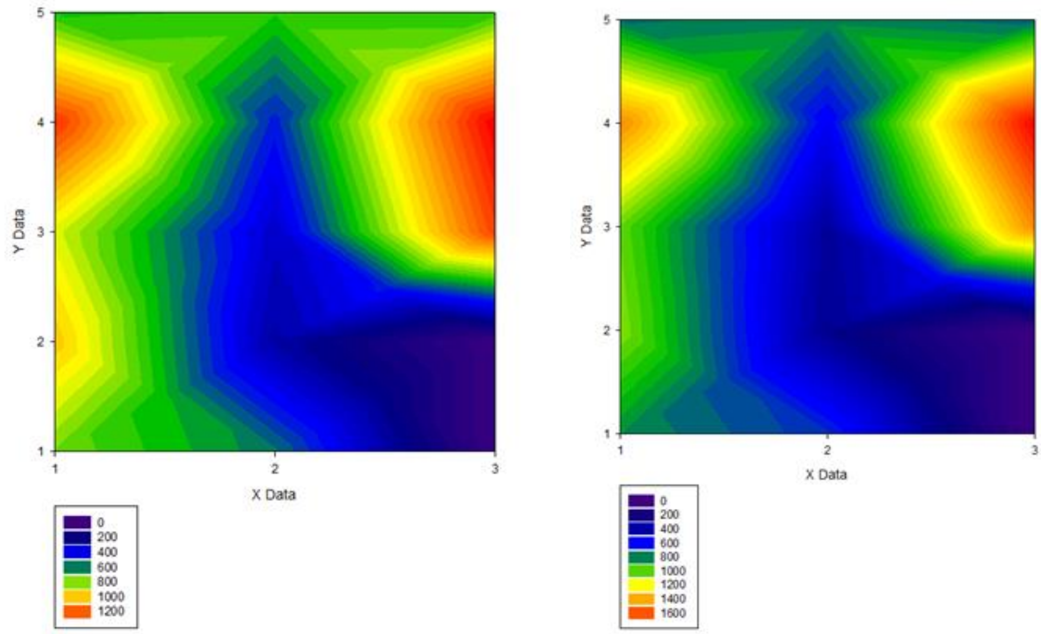
Fig. 5 *Layout of Room 2: Mechatronic Engineering Laboratory*

Table 2 shows the comparison between Lux Meter and Prototype for Room 2: Mechatronic Engineering Laboratory based on the location of the lamp point. The data that has been measured from the lux meter and prototype has been placed in this table. After that, the analysis of the comparison of percentage differences will be described.

Table 2 *Comparison of luminescence for Room 2: Mechatronic Engineering Laboratory*

Point, N	Lux Meter, lx	Prototype, lx
A1	671	748
A2	1252	1458
A3	859	990
A4	988	1033
A5	755	801
B1	684	781
B2	460	553
B3	331	342
B4	268	311
B5	570	649
C1	689	734
C2	1355	1784
C3	1224	1454
Total Average, x_i	777.38	895.23
Mean, μ	59.799	68.863
Variance, σ^2	1657.831	4233.831
Standard Deviation, σ	40.72	65.08

Table 2 revealing variations in Lux values at each point. The calculated average Lux values are 777.38 lx for Lux Meter and 895.23 lx for Prototype, exceeding the Malaysian Standard (MS) recommendation of 500 lux. Despite both averages surpassing the standard, a 13.72% difference exists between Lux Meter and Prototype. Standard deviations of 40.72 lx for Lux Meter and 65.08 lx for Prototype highlight Lux variability. The laboratory's role in mechatronic engineering emphasizes the significance of optimal lighting for interdisciplinary activities involving mechanical, electronic, and computer engineering. Higher Lux values enhance visibility, crucial for intricate tasks such as circuit assembly, sensor calibration, and working with electronic and mechanical components. This improved visibility mitigates the risk of errors during hands-on projects, ultimately contributing to the quality and efficiency of mechatronic engineering activities.



(a) (b)

Fig. 6 *Illuminance contour from (a) Lux meter and (b) Prototype for Room 2: Mechatronic Engineering Laboratory*

Fig. 6 displays the illuminance levels in Room 2: Mechatronic Engineering Laboratory measured by the Lux meter. Brighter colours represent higher lux values, while darker colours indicate lower lux values. Some points in the contour, shown in blue, are below 400 lux due to broken lamps. This contributes to the room falling below the Malaysian standard, highlighting the impact of malfunctioning lamps on the overall illuminance.

3.3 Room 3: Lecture Room 1

For Room 3: Lecture Room 1 there are 9 points of lamp with area of 7m × 6m in this room. Fig. 7 shows the layout of Room 3: Lecture Room 1. The division of points for horizontal was 3 points which is A, B and C and for the vertical division is 3 points. The point will be written as A1 until C3 based on the point location in the room.

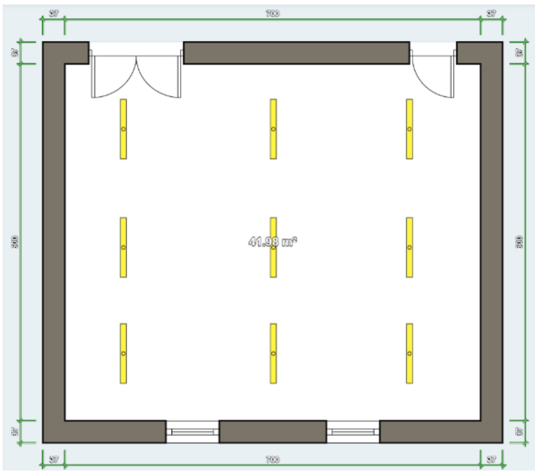


Fig. 7 *Layout of Room 3: Lecture Room 1*

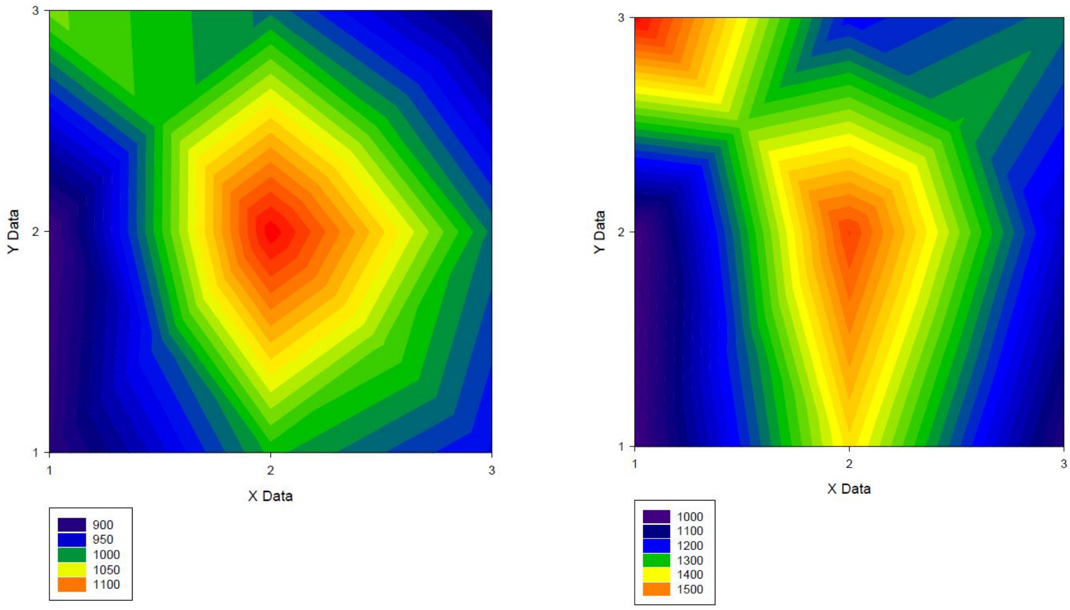
Table 3 shows the Comparison between the Lux Meter and the Prototype for Room 3: Lecture Room 1 based on the location of the lamp point. The data that has been measured from the lux meter and prototype has been placed in this table. After that, the analysis of the comparison of percentage differences will be described.

Table 3 reveals average Lux values of 970.33 lx for Lux Meter and 1238.78 lx for Prototype. The average percentage difference is 32.77%, signifying a moderate disparity. Standard deviations of 121.82 lx for Lux Meter and 134.27 lx for Prototype showcase Lux variability. Despite exceeding the Malaysian Standard (MS) recommendation of 300-500 lux for classrooms, these Lux values are fitting for a lecture room. The purpose of a lecture room, where students actively participate in lectures, discussions, and note-taking, underscores the significance of lighting conditions. Higher Lux values positively contribute to student engagement, concentration, and overall comfort. The increased lighting intensity reduces eye strain and fatigue, creating an optimal learning environment that supports attentiveness and active participation. Adequate lighting also enhances the effectiveness of visual aids, note-taking, and overall educational experiences, aligning with conducive lighting requirements for a lecture room and ensuring students can fully benefit from academic activities and discussions.

Table 3 *Comparison of luminescence for Room 3: Lecture Room 1*

Point, N	Lux Meter, lx	Prototype, lx
A1	1023	1591
A2	877	986
A3	889	993
B1	956	1189
B2	1137	1542
B3	1003	1411
C1	903	1250
C2	987	1148
C3	958	1039
Total Average, x_i	970.33	1238.78
Mean, μ	107.81	137.64
Variance, σ^2	14837.7	18013.93
Standard Deviation, σ	121.82	134.27

Fig, 8 presents an illuminance contour for Room 3: Lecture Room, visually representing Lux Meter data. The contour uses a color spectrum to indicate varying lux values, revealing a uniformly bright environment that surpasses the Malaysian Standard for classroom and library lighting (300-500 lux). Two key factors contribute to the room's brightness: the height of the room and the strategic placement of tables. The room's height aids in the uniform spread of artificial lighting, while the absence of furniture in the central area allows for unobstructed light distribution. The central placement of artificial lighting is crucial, ensuring a balanced and widespread distribution of lux values. As a result, the central area exhibits the highest illuminance values in the contour. This design choice, combined with thoughtful positioning of light sources and minimal obstruction, contributes to the overall brightness and uniformity of the lecture room, creating an optimal environment for educational activities



(a) (b)

Fig. 8 *Illuminance contour from (a) Lux meter and (b) Prototype for Room 3: Lecture Room 1*

3.4 Room 4: Tutorial Room 1

For Room 4: Tutorial Room 1 there are 9 points of lamp with area of 7m × 6m in this room. Fig. 9 shows the layout of Room 4: Tutorial Room 1. The division of points for horizontal was 3 points which is A, B and C and for the vertical division is 3 points. The point will be written as A1 until C3 based on the point location in the room.

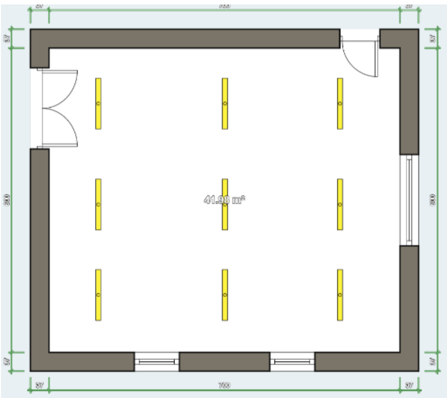
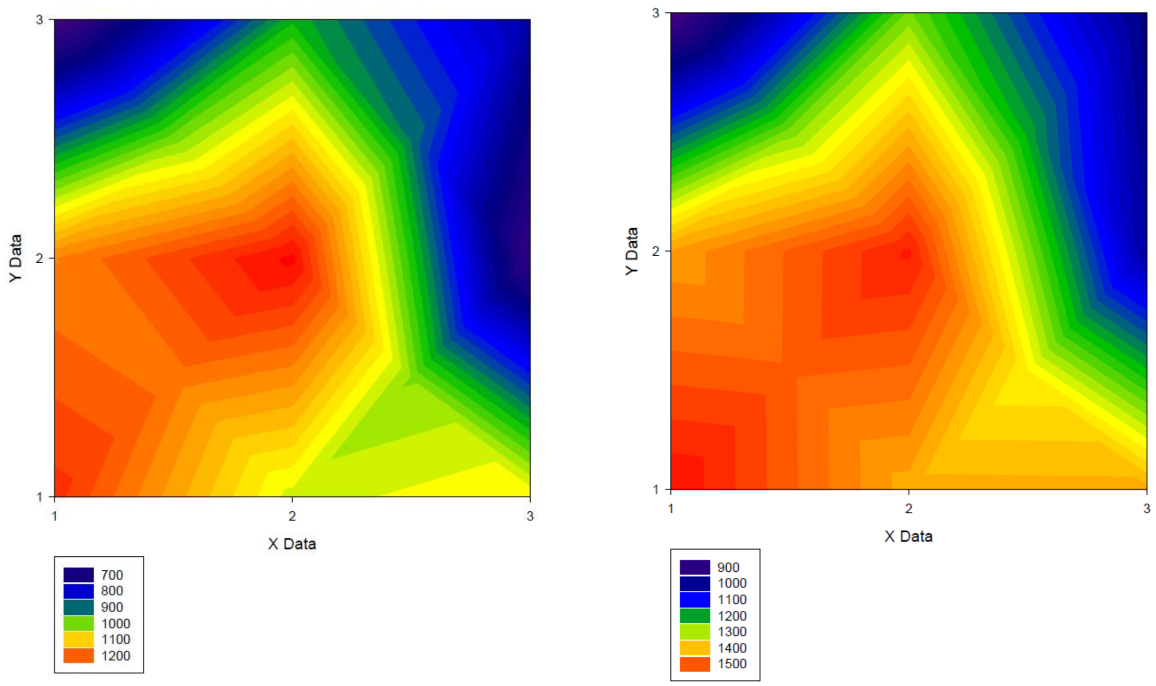


Fig. 9 *Layout of Room 4: Tutorial Room 1*

Table 4 compares Lux Meter and Prototype data for Room 4: Tutorial Room based on lamp point locations. The table presents the measured data from both the Lux Meter and Prototype. Subsequently, an analysis of the percentage difference between the two sets of data will be provided

Table 4 *Comparison of luminescence for Room 4: Tutorial Room 1*

Point, N	Lux Meter, lx	Prototype, lx
A1	601	841
A2	1159	1422
A3	1229	1561
B1	934	1264
B2	1266	1544
B3	1030	1409
C1	751	964
C2	634	998
C3	1058	1407
Total Average, x_i	962.44	1267.77
Mean, μ	106.94	140.86
Variance, σ^2	2845.20	4069.32
Standard Deviation, σ	53.34	67.91



(a) (b)

Fig. 10 *Illuminance contour from (a) Lux meter and (b) Prototype for Room 4: Tutorial Room 1*

Table 4 displays average Lux values of 962.44 lx for Lux Meter and 1267.77 lx for Prototype. The average percentage difference is 33.61%, indicating a moderate disparity, while standard deviations of 53.34 lx for Lux Meter and 67.91 lx for Prototype highlight Lux variability. Despite surpassing the Malaysian Standard (MS) recommendation of 300-500 lux for classrooms and libraries, the higher Lux values in the tutorial room are advantageous for small-group sessions. These sessions involve active student participation, discussions, and collaborative problem-solving. The increased lighting intensity positively impacts the learning environment, promoting visibility, focused discussions, and active engagement. Adequate lighting reduces eye strain, creating a comfortable atmosphere for collaborative learning and tutorial activities. The Lux values observed align with the requirements of a tutorial room, contributing to an environment that facilitates effective interaction between students and tutors, ultimately enhancing the overall educational experience in this instructional space.

Fig. 10 displays the illuminance levels in Room 4: Tutorial Room as measured by the Lux meter. Brighter colour represents higher lux values, and the entire room appears bright. This brightness surpasses the Malaysian Standard due to the use of LED lamps, which emit high illuminance, making the room exceptionally bright

4. Conclusion

The work concludes with success in achieving its objectives, enhancing knowledge in electrical design and device communication. IoT helps the lux meter by reducing the shadow when the measurement is taken. Recommendations for future improvements include integrating diverse sensors for specific functions, using STM32 or Raspberry Pi for higher performance, and incorporating a solar battery to store excess energy more effectively than the current TP4056 module.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Izzat Mirza Mohd Yusof, Rosnah Mohd Zin;* ***data collection:*** *Muhammad Izzat Mirza Mohd Yusof;* ***analysis and interpretation of results:*** *Muhammad Izzat Mirza Mohd Yusof;* ***draft manuscript preparation:*** *Muhammad Izzat Mirza Mohd Yusof, Rosnah Mohd Zin. All authors reviewed the results and approved the final version of the manuscript.*

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