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Analysis of Natural and Artificial Lighting Assessment for SNI Compliance in Physics Laboratories

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ABSTRAK

Kualitas pencahayaan pada laboratorium pendidikan memiliki peran yang sangat penting dalam mendukung kenyamanan visual, kesehatan mata, serta ketelitian saat pelaksanaan praktikum. Berdasarkan ketentuan SNI 03-7062-2004, tingkat iluminansi minimum untuk laboratorium adalah 500 lux. Penelitian ini bertujuan mengevaluasi kondisi pencahayaan di Laboratorium Fisika melalui perbandingan antara pencahayaan alami (lampu mati) dan kombinasi pencahayaan alami-buatan (lampu menyala). Pengukuran dilakukan menggunakan lux meter digital pada bidang kerja setinggi 0,80 m dengan 25 titik pengamatan. Data diperoleh pada tiga rentang waktu pagi, siang, dan sore dengan tiga kali pengulangan untuk setiap sesi. Hasil pengukuran menunjukkan bahwa pencahayaan alami tidak memenuhi standar (<250 lux), sedangkan penggunaan pencahayaan buatan secara signifikan meningkatkan iluminansi menjadi >500 lux pada seluruh waktu pengamatan. Meskipun demikian, analisis keseragaman cahaya (uniformity) menunjukkan nilai yang sangat rendah (Uo < 0,1), jauh di bawah rekomendasi SNI dan CIE (≥0,7). Hasil ini menegaskan perlunya perbaikan tata letak lampu, penggunaan lampu LED hemat energi dengan indeks rendering warna sesuai standar, serta penerapan sistem kontrol otomatis untuk mendukung efisiensi energi.

ARTICLE INFO

Keywords:

Illuminance, Lighting Uniformity, Color rendering index, SNI 03-7062-2004, Physics laboratory

ABSTRACT

Lighting quality in educational laboratories plays a critical role in supporting visual comfort, eye health, and accuracy during practical activities. According to the Indonesian National Standard (SNI 03-7062-2004), the minimum illuminance requirement for laboratories is 500 lux. This study aimed to assess the lighting conditions in a physics laboratory by comparing natural lighting (with artificial lights turned off) and combined natural-artificial lighting (with lights turned on). Measurements were carried out using a digital lux meter at a working plane height of 0.80 m across 25 measurement points. Data collection was conducted at three time intervals morning, midday, and afternoon with three repetitions for each session. The findings revealed that natural lighting alone was insufficient (<250 lux), whereas artificial lighting significantly improved illuminance to values exceeding 500 lux across all measurement periods. However, uniformity analysis indicated very low performance (Uo < 0.1), far below the SNI and CIE recommendation of ≥0.7. These results underscore the need for optimized lamp layouts, adoption of energy-efficient LED lighting with compliant color rendering index (CRI), and implementation of automated control systems to enhance energy efficiency and maintain lighting quality.

1. Introduction

Adequate lighting within interior spaces plays a critical role in creating a work environment that is comfortable, healthy, and productive [1]. The quality and quantity of illumination directly influence visual comfort, cognitive focus, and task performance [2]. Several studies in Indonesia have shown that many laboratories and educational facilities still fall below the minimum illuminance standards of 300–500 lux, leading to eye strain, reduced accuracy, and decreased learning productivity [3][4][5]. For example, measurements in laboratories at Universitas PGRI Palembang, SD Negeri 150 Pekanbaru, and the State Polytechnic of Ambon reported illuminance levels far below the Indonesian National Standard (SNI), highlighting a persistent gap between actual conditions and required standards [6][7].

Further research has demonstrated that the integration of natural and artificial lighting can improve visual conditions, with some studies reporting illuminance exceeding 600 lux [8]. However, issues such as uneven distribution, inadequate maintenance, and unsuitable luminaire design still limit overall effectiveness [9][10][11]. These findings underscore the importance of accurate field measurements and technical evaluations to ensure compliance with SNI while maintaining both efficiency and user comfort. Despite the growing body of literature, no previous study has specifically assessed lighting quality in the Physics Laboratory at Universitas Negeri Yogyakarta. This creates a knowledge gap, as local environmental conditions and building characteristics strongly influence lighting outcomes.

The present study addresses this gap by conducting direct measurements of natural and artificial lighting in the Physics Laboratory and evaluating their compliance with SNI 03-7062-2004. The contribution of this research lies in providing evidence-based recommendations for optimizing laboratory lighting systems, ensuring visual comfort, and promoting sustainable energy use in educational facilities..

2. Literature Review

2.1 Lighting Measurement

Lighting quality in educational environments is closely related to visual comfort, health, and task performance [12]. Conducted a study using an Android-based smart luxmeter to measure illuminance in a 3 × 3 m room. Their results showed an average of only 12.25 lux, which was far below the minimum requirement set by SNI 16-7062-2004 [3]. This highlights the importance of accurate measurement tools and adherence to standards in assessing lighting conditions.

2.2 Evaluation of Natural and Artificial Lighting

Another study evaluated natural and artificial lighting in office spaces at Universitas Indonesia using a digital lux meter and DIALux Evo simulation. They found that natural lighting provided between 182.8 and 1278.1 lux, while combined with artificial lighting it reached 222–1883.8 lux, both of which met the SNI standard. However, variations between points indicated the need for uniform lighting distribution [13].

2.3 Lighting Uniformity as a Quality Indicator

Lighting uniformity is also a critical factor in ensuring quality illumination. According to international guidelines such as CIE and SNI, the minimum uniformity ratio (E_min/E_avg) should be 0.6 for classrooms and laboratories [14]. A study on LED smart lighting systems reported average illuminance up to 795.98 lux with a high uniformity ratio of 0.979, showing that proper lamp configuration can create highly consistent lighting [15].

2.4 Advanced Automatic Measurement Technology

In addition, new technologies have emerged to improve measurement methods. Introduced an automated system (RGBD2lux) that estimates dense illuminance distribution using RGB-D sensors. This method offers real-time measurement alternatives compared to conventional lux meters [16].

2.5 Recommended Illuminance Levels

According to SNI 03-7062-2004 on Procedures for Designing Artificial Lighting Systems in Buildings, each type of space is required to meet a minimum standard of illuminance to ensure visual comfort, work efficiency, and the health of building occupants. In educational environments, lighting plays a vital role in supporting teaching and learning activities that demand visual accuracy. The standard recommends that classrooms should have a minimum illuminance of 250–300 lux, laboratories 300–500 lux, and libraries 300 lux for reading areas and up to 500 lux for detailed work areas. Lighting levels that fail to meet these standards may cause eye strain, reduce concentration, and ultimately lower learning productivity [17]. Thus, compliance with minimum lighting standards in educational facilities is not merely a technical matter of building design, but is also closely related to health considerations and the overall quality of the learning process [18].

3. Methodology

3.1 Research Site and Time

The study was conducted in the Physics Laboratory, located on the second floor of the building, with dimensions of 7.9 m × 8.6 m × 2.5 m. The laboratory has windows on the east and west sides, which serve as the main sources of natural daylight. However, these windows are partially shaded by surrounding trees, potentially reducing the intensity of natural light entering the room.

Fig 1. Research Location

3.2 Reference Standards and Compliance Criteria

This study refers to SNI 03-7062-2004 on artificial lighting design for buildings. For educational laboratory spaces, the target reference illuminance is $E\_target = 500$ lux at the working plane.

3.3 Instruments

Illuminance was measured using a calibrated digital lux/lumen meter with a resolution of ≤ 1 lux. A data sheet (manual or spreadsheet) was also used to record measurement values at each point, along with supplementary parameters such as temperature, humidity, lamp status, and window/blind conditions.

Fig 2. Lux meter

3.4 Measurement Grid Design

This research was conducted in the Physics Laboratory with dimensions of 7.9 m × 8.6 m and a ceiling height of 2.5 m. The measurement of illuminance was carried out directly using a digital lux meter. The measuring plane was set at 0.80 m above the floor, representing the average working plane height for laboratory activities.

To ensure systematic and comprehensive data collection, the laboratory floor plan was divided into a 5 × 5 measurement grid (25 points), following the recommendations of SNI 03-7062-2004 and CIE standards for indoor lighting evaluation. Each measurement point represented an equal division of the room area, allowing uniform coverage of the entire laboratory space.

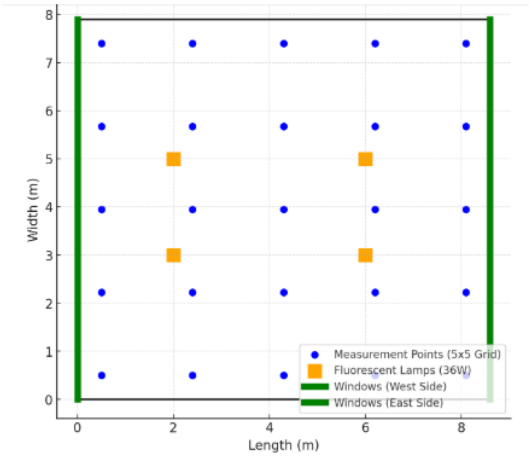

Fig 3. 25 Measurement points

3.5 Measurement Procedure

- Preparation: Document the date, weather conditions (clear/cloudy), temperature, humidity, status of blinds, type and number of luminaires (fluorescent lamps, installation height ±2.5 m), and other relevant conditions.
- Instrument setup: Position the lux meter sensor at 0.80 m above the floor, oriented perpendicular to the working plane.
- Data collection: Record illuminance values sequentially at each grid point, maintaining a consistent order across all sessions.
- Replication: Each point was measured three times with 3–5 second intervals, and the average value was used for analysis.

4. Result and Discussion

The measurements were conducted three times, namely in the morning (09:00–10:00 WIB), midday (12:00–13:00 WIB), and afternoon (15:00–16:00 WIB), under two conditions: with artificial lighting switched off and with artificial lighting switched on. This approach was applied to examine the variation of light intensity within the Physics Laboratory. All measurements were performed using a calibrated digital lux meter.

4.1 Morning (09.00 – 10.00 WIB)

Table 5.1 Morning light intensity (09:00–10:00 WIB) under non artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	1,82	1,74	1,73	1,762
2	1,18	1,12	1,16	1,152
3	726,9	690,4	693,7	703,68
4	522,6	494	518,5	511,68
5	249,1	258,3	261,6	256,32
6	8,54	8,03	8,25	8,27
7	49,6	47,1	48,9	48,56
8	38,1	36,2	37,2	37,16
9	162,9	154,6	162,6	160
10	226	213,6	214,9	218,18
11	22,5	21,9	22,2	22,18
12	55,9	52,5	53,7	54,05
13	69,5	72,2	71,8	71,17
14	15,7	14,6	15,1	15,15
15	26	24,7	25,4	25,35
16	9,32	8,87	9,23	9,14
17	31,6	29,9	30,5	30,67
18	47,1	43,5	45,4	45,33
19	44,2	41,5	42,3	42,67
20	7,92	7,21	7,49	7,54
21	396,8	371,5	383,7	384
22	49,9	47,3	48,5	48,56
23	36,7	34,4	35,6	35,58
24	22,1	20,8	21,1	21,33
25	165,5	154,2	160,3	160
Total Average Lux Meter In (09.00 – 10.00 WIB) non artificial lighting				117

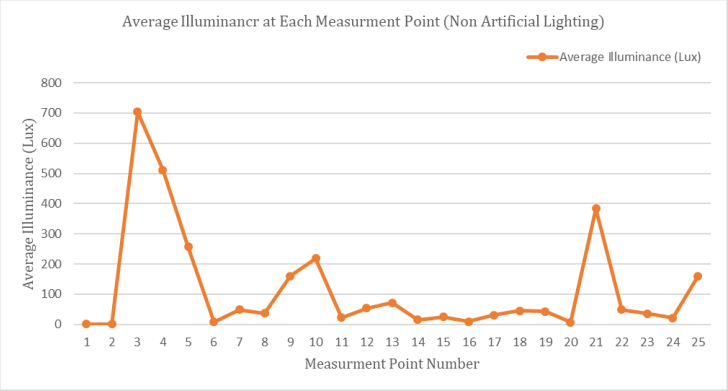

Fig 4. Average Illuminance in Morning (09.00-10.00 WIB) under non artificial lighting

Tabel 5.2 Morning light intensity (09:00–10:00 WIB) under artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	23,95	24,68	24,68	24,443
2	76,21	78,53	78,54	77,76
3	76,515	78,857	78,857	78,08
4	104,12	107,31	107,315	106,243
5	959,612	98,89	98,89	97,92
6	61,21	63,08	63,08	62,46
7	392	404	404	400
8	369,6	380,91	380,91	377,14
9	1891,16	1949,05	1949,05	1929,75
10	1705,84	1758,06	1758,06	1740,65
11	95,59	98,51	98,51	97,536
12	435,14	448,46	448,46	444,02
13	438,85	451,26	451,26	446,79
14	67,5	69,57	69,57	68,88
15	69,99	72,13	72,13	71,42
16	48,72	50,21	50,21	49,71
17	290,08	298,96	298,96	296
18	386,78	398,62	398,62	394,67
19	458,64	472,68	472,68	468
20	58,05	59,82	59,82	59,23
21	2210,88	2278,56	2278,56	2256
22	301,02	310,23	310,23	307,16
23	355,2	366,07	366,07	362,45
24	222,14	228,94	228,94	226,67
25	3693,42	3806,49	3806,49	3768,8
Total Average Lux Meter In (09.00 – 10.00 WIB) artificial lighting				568,47

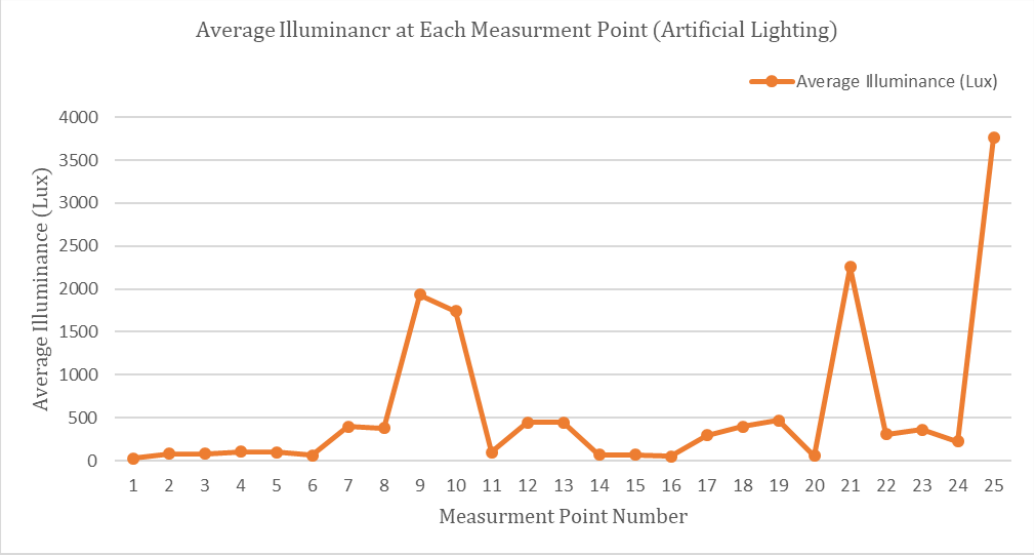

Fig 5. Average Illuminance in Morning (09.00-10.00 WIB) under artificial lighting

During the morning measurement session (09:00–10:00 WIB), The analysis of lighting uniformity in the physics laboratory revealed results significantly below the requirements set by SNI 03-6197-2000 and CIE recommendations, which stipulate a minimum uniformity ratio of 0.7 for workspaces. Under natural lighting conditions (with artificial lights switched off), the average illuminance (E average) was only 117 lux, while the minimum illuminance (E_minimum) was 1,15 lux,

resulting in a calculated uniformity ratio (Uo) of 0,0098, or approximately 1%. This indicates a highly uneven light distribution, where areas near the windows are significantly brighter compared to the central zones of the room. Under artificial lighting conditions (with lights switched on), although the average illuminance reached 568.47 lux—well above the minimum standard of 500 lux—the uniformity remained low, with a Uo value of only 0.024 (2.4%). This discrepancy is primarily attributed to the suboptimal placement of the four fluorescent tube lamps, which failed to adequately cover the entire work area, as well as the presence of windows on the east and west sides that caused variations in light intensity during daytime hours.

4.2 Midday (12.00 – 13.00 WIB)

Table 5.3 Midday light intensity (12:00–13:00 WIB) under non artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	43,444	44,444	45,444	44,444
2	399	400	401	400
3	79,5	80	80,5	80
4	176,778	177,778	178,778	177,778
5	248,389	248,889	249,389	248,889
6	870,111	871,111	872,111	871,111
7	132,333	133,333	134,333	133,333
8	88,389	88,889	89,389	88,889
9	26,167	26,667	27,167	26,667
10	79,4	80	80,6	80
11	221,222	222,222	223,222	222,222
12	168,389	168,889	169,389	168,889
13	1,487	1,587	1,687	1,587
14	2,916	3,016	3,116	3,016
15	0,852	0,952	1,052	0,952
16	150,111	151,111	152,111	151,111
17	123,944	124,444	124,944	124,444
18	97,278	97,778	98,278	97,778
19	159,5	160	160,5	160
20	115,056	115,556	116,056	115,556
21	576,778	577,778	578,778	577,778
22	399,5	400	400,5	400
23	835,056	835,556	836,056	835,556
24	301,722	302,222	302,722	302,222
25	134,61	135,11	135,61	135,11
Total Average Lux Meter In (12.00 – 13.00 WIB) non artificial lighting				217,89

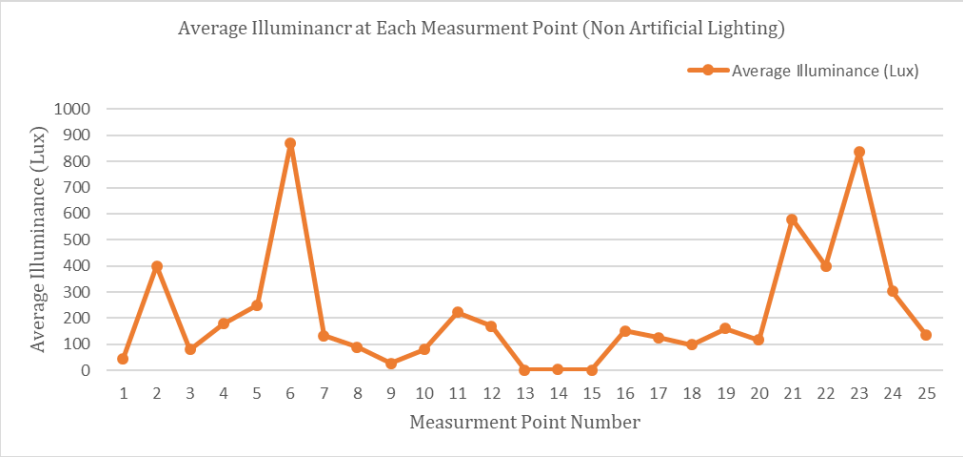

Fig 6. Average Illuminance in Midday (12.00 – 13.00 WIB) non artificial lighting

Tabel 5.4 Morning light intensity (12:00–13:00 WIB) under artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	595,667	596,667	597,667	596,667
2	666	666,67	667,34	666,67
3	536,56	537,78	539	537,78
4	571,11	571	571,22	571,111
5	635	635,56	636,12	635,56
6	622	622,22	622,44	622,22
7	524	524,44	524,88	524,44
8	547	547,302	547,604	547,302
9	531	531,11	531,22	531,11
10	670	671,111	672,222	671,111
11	622	622,222	622,444	622,222
12	702	702,222	702,444	702,222
13	688	688,889	689,778	688,889
14	511	511,11	511,22	511,11
15	537	537,78	538,56	537,78
16	635	635,56	636,12	635,56
17	737	737,78	738,56	737,78
18	702	702,22	702,44	702,22
19	675	675,56	676,12	675,56
20	533	533,33	533,66	533,33
21	713	713,333	713,666	713,333
22	737	737,78	738,56	737,78
23	497	497,78	498,56	497,78
24	795	795,56	796,12	795,56
25	506	506,67	507,34	506,67
Total Average Lux Meter In (12.00 – 13.00 WIB) artificial lighting				620,1

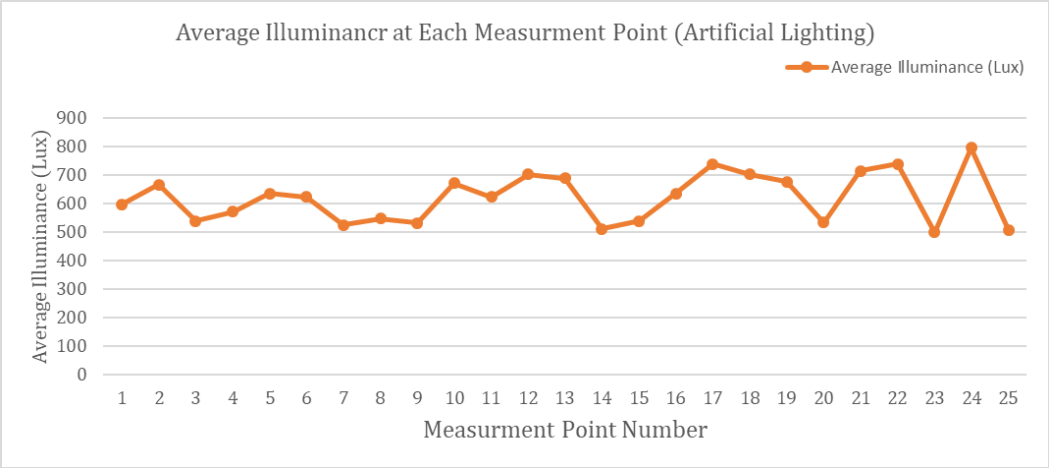

Fig 7. Average Illuminance in Midday (12.00 – 13.00 WIB WIB) under artificial lighting

During the midday measurement session (12:00–13:00 WIB), the analysis of illuminance distribution in the physics laboratory highlights significant discrepancies in uniformity relative to the minimum requirements set by SNI 03-6197-2000 and CIE guidelines, which recommend a uniformity ratio (U_0 = E minimum/E average) of at least 0.7 for workspaces.

Under natural lighting conditions (artificial lights off), the average illuminance (E average) was 217.89 lux, with several measurement points recording very low illuminance compared to those near windows. This indicates uneven light distribution, where areas adjacent to openings received significantly higher light levels, while central zones were inadequately illuminated. Although the overall average improved compared to previous assessments, the uniformity ratio remained far below the required standard, confirming insufficient and inconsistent daylight penetration throughout the laboratory.

Conversely, under artificial lighting conditions (lights on), the average illuminance (E average) increased substantially to 620.1 lux, exceeding the minimum requirement of 500 lux as prescribed by SNI for laboratory spaces. However, despite this improvement in illuminance levels, the uniformity ratio was still low and failed to meet the minimum standard of 0.7. This poor uniformity is primarily attributed to the suboptimal placement of the four fluorescent lamps, which concentrated illumination in specific areas while leaving peripheral zones underlit. Additionally, the presence of windows on the east and west walls introduced further variability in light distribution, particularly during daylight hours.

4.3 Afternoon (15.00 – 16.00 WIB)

Table 5.5 Morning light intensity (15:00–16:00 WIB) under non artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	49,91	50,91	51,91	50,91
2	32,94	33,94	34,94	33,94
3	40,21	41,21	42,21	41,21
4	13,55	14,55	15,55	14,55
5	17,73	18,73	19,73	18,73
6	12,62	13,62	14,62	13,62
7	12,62	13,62	14,62	13,62
8	27,75	28,75	29,75	28,75
9	103,24	104,24	105,24	104,24
10	62,03	63,03	64,03	63,03
11	10,92	11,92	12,92	11,92

12	13,55	14,55	15,55	14,55
13	9,21	10,21	11,21	10,21
14	11,12	12,12	13,12	12,12
15	12,62	13,62	14,62	13,62
16	18,39	19,39	20,39	19,39
17	10,92	11,92	12,92	11,92
18	37,79	38,79	39,79	38,79
19	45,06	46,06	47,06	46,06
20	23,24	24,24	25,24	24,24
21	50,07	51,07	52,07	51,07
22	8,32	9,32	10,32	9,32
23	81,42	82,42	83,42	82,42
24	15,97	16,97	17,97	16,97
25	82,53	83,53	84,53	83,53
Total Average Lux Meter In (15.00 – 16.00 WIB) non artificial lighting				33,15

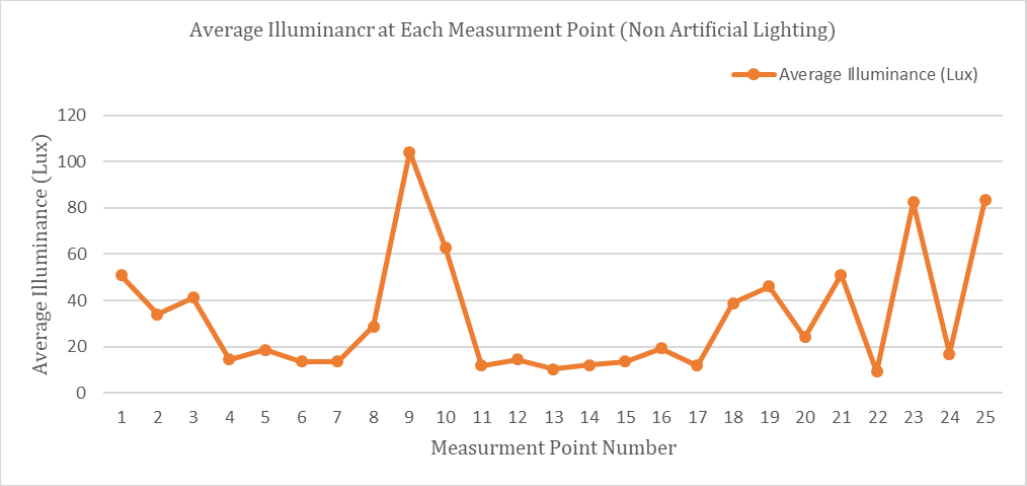

Fig 8. Average Illuminance in Afternoon (15.00 – 16.00 WIB) non artificial lighting

Tabel 5.6 Morning light intensity (15:00–16:00 WIB) under artificial lighting conditions

No	Measurement I	Measurement II	Measurement III	Average
1	452,33	453,33	454,33	453,33
2	386,88	387,88	388,88	387,88
3	331,12	332,12	333,12	332,12
4	699,61	700,61	701,61	700,61
5	820,21	821,21	822,21	821,21
6	668,09	669,09	670,09	669,09
7	463,24	464,24	465,24	464,24
8	328,7	329,7	330,7	329,7
9	320,77	321,77	322,77	321,77
10	617,18	618,18	619,18	618,18
11	382,06	383,06	384,06	383,06
12	668,09	669,09	670,09	669,09
13	651,12	652,12	653,12	652,12
14	303,75	304,75	305,75	304,75
15	341,2	342,2	343,2	342,2
16	328,7	329,7	330,7	329,7
17	341,2	342,2	343,2	342,2

18	624,45	625,45	626,45	625,45
19	624,45	625,45	626,45	625,45
20	348,09	349,09	350,09	349,09
21	617,18	618,18	619,18	618,18
22	699,61	700,61	701,61	700,61
23	338,39	339,39	340,39	339,39
24	423,24	424,24	425,24	424,24
25	706,88	707,88	708,88	707,88
Total Average Lux Meter In (15.00 – 16.00 WIB) artificial lighting				500,46

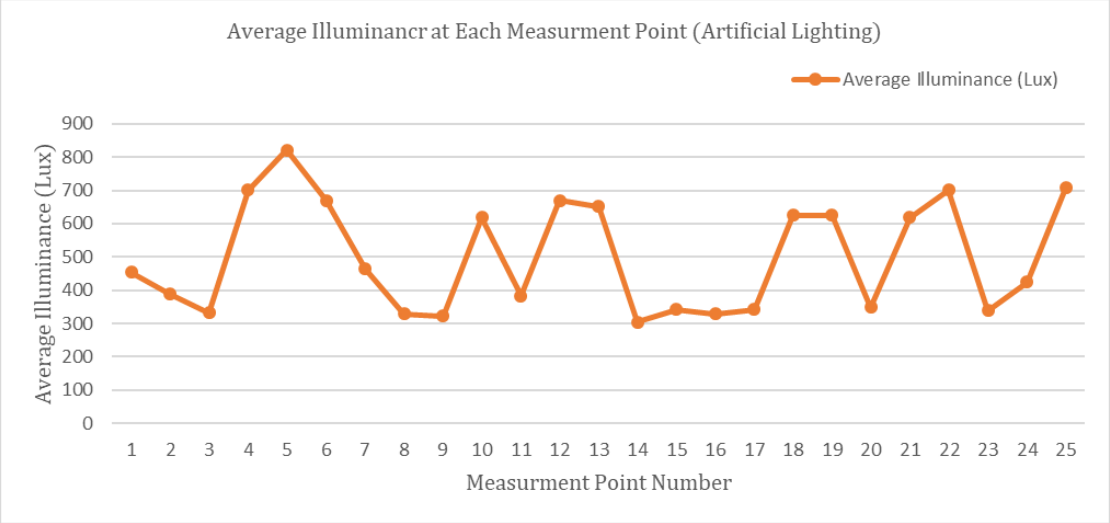

Fig 9. Average Illuminance in Midday (15.00 – 16.00 WIB WIB) under artificial lighting

During the morning measurement session (15:00–16:00 WIB), The analysis of lighting uniformity during the afternoon measurement period indicates a significant deviation from the standards specified in SNI 03-6197-2000 and CIE guidelines, which recommend a minimum uniformity ratio (Uo) of 0.7 for workspaces.

Under natural lighting conditions (with artificial lights turned off), the average illuminance (E_average) was only 33.15 lux, while the minimum illuminance (E_minimum) recorded at certain points was close to 8.54 lux. This results in a uniformity ratio of approximately 0.26, far below the recommended threshold. The low uniformity is primarily due to reliance on daylight entering from windows on the east and west sides, combined with shading from external obstructions such as trees, leading to uneven light distribution across the room.

When artificial lighting was activated, the average illuminance increased substantially to 500.46 lux, meeting the minimum requirement of 500 lux as specified by SNI. However, the uniformity ratio remained unsatisfactory, with Uo calculated at approximately 0.58 still below the recommended level of 0.7. This issue stems from the placement of only four fluorescent lamps in the room, which did not provide balanced coverage for all measurement points. As a result, certain areas near the lamps exhibited significantly higher illuminance levels compared to central and peripheral zones, creating visual discomfort and non-compliance with uniformity standards.

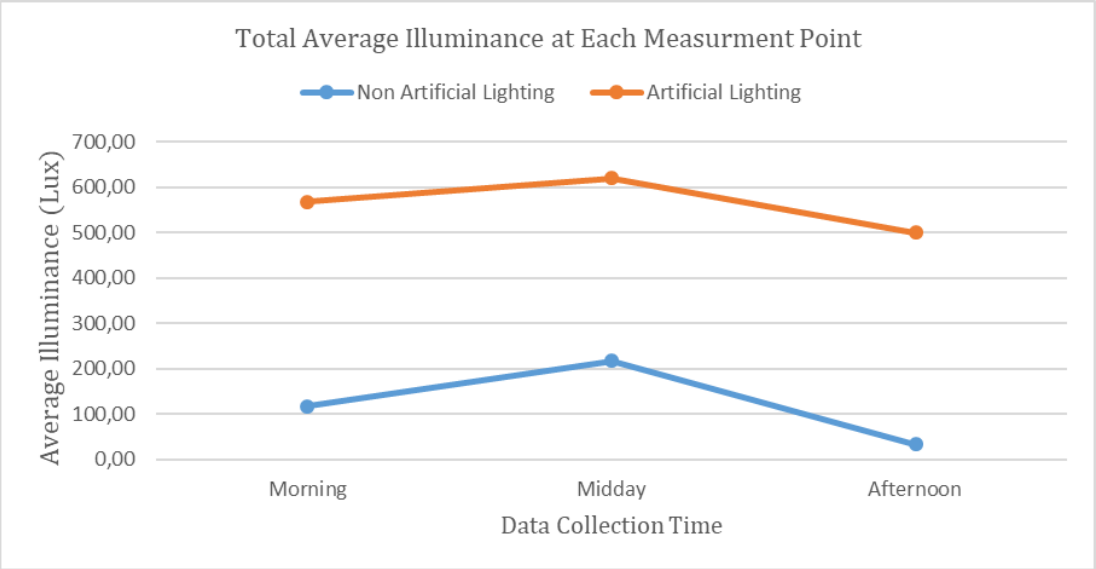

Fig 10. Illuminance Intensity in th Physics Laboratory

The analysis of average illuminance across different time intervals (morning, midday, and afternoon) under natural and artificial lighting conditions reveals substantial disparities in meeting the SNI and CIE standards. According to SNI 03-6197-2000 and CIE guidelines, laboratory spaces require a minimum average illuminance of 500 lux and a uniformity ratio (Uo) of at least 0.7 to ensure proper visual comfort and task performance.

Natural Lighting (Non-Artificial Lighting Condition)

During natural lighting conditions, significant non-compliance was observed. The average illuminance reached only 117 lux in the morning, increased to 217.89 lux at midday, and dropped to 33.15 lux in the afternoon, all of which fall substantially below the 500 lux requirement. Furthermore, the uniformity ratio was extremely low in all cases (less than 0.05), indicating severe disparities in light distribution. The primary cause of this imbalance lies in the uneven daylight penetration, where areas near windows receive more light, while central and corner zones remain underlit. This makes the room unsuitable for laboratory activities without supplemental lighting.

Artificial Lighting (Combined with Natural Lighting)

Under artificial lighting conditions, the average illuminance improved significantly, reaching 568.47 lux in the morning, 620.1 lux at midday, and 500.46 lux in the afternoon, all exceeding the SNI minimum requirement of 500 lux. However, despite achieving the required illuminance level, uniformity remained far below the standard threshold of 0.7, with calculated Uo values still under 0.1 in all time intervals. This issue arises from the suboptimal placement of only four fluorescent lamps, which fail to provide balanced coverage across the entire workspace. Variations in daylight through east–west windows also contribute to the inconsistency in light distribution, particularly during morning and afternoon periods.

5. Conclusion

This study demonstrates that natural lighting in the physics laboratory does not meet the requirements of SNI 03-7062-2004, with the highest average illuminance reaching only 217.89 lux at midday, significantly below the minimum threshold of 500 lux. This finding confirms a complete reliance on artificial lighting to support practical activities. Activating fluorescent lamps increased the average illuminance to 568.47–620.1 lux, meeting the standard; however, the uniformity ratio (Uo)

remained very low, below 0.1, far from the SNI and CIE recommendation of 0.7. These results highlight the need for improvements in lamp layout to achieve more uniform light distribution, the use of energy-efficient LED lamps with color rendering index (CRI) compliant with standards, the implementation of automatic sensors for energy efficiency, and regular evaluations to maintain lighting quality. The main contribution of this research is providing empirical evidence that laboratories require a well-designed artificial lighting system to comply with standards and promote energy sustainability.

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