

Comparative Analysis of Student Comfort Between Ideal and Existing Classrooms Based on Thermal and Lighting Conditions

Dewanda Adi Nur Hidayat*, Febri Liantoni, Cucuk Wawan Budiyo

Universitas Sebelas Maret (UNS) Surakarta, Indonesia

dewandaadi.nurhidayat@gmail.com*

Abstract

This study aims to analyze the differences in students' comfort levels between classrooms with ideal temperature and lighting conditions and those with existing conditions. Physical environmental conditions significantly influence students' concentration and learning effectiveness; however, a critical gap often exists between the ideal environmental parameters established in educational design and the actual conditions experienced by students in daily learning activities. A quantitative quasi-experimental comparative design was employed, involving 32 tenth-grade students of the TJKT program at SMK Negeri 2 Surakarta. To control for individual perceptual biases, a within-subjects design was utilized, wherein all students experienced and evaluated both conditions. Data were collected using a 40-item comfort questionnaire covering thermal comfort, visual comfort, and learning environment support, which demonstrated high reliability (Cronbach's Alpha = 0.979). Data were analyzed using paired sample t-tests. The results revealed a significant difference in comfort scores between the ideal classroom ($M = 142.00$) and the existing classroom ($M = 111.19$), with $t(15) = 26.919$, $p < 0.001$. These findings demonstrate that optimizing temperature and lighting conditions substantially enhances student comfort, underscoring the need for targeted physical environment improvements in educational facilities.

Keywords: student comfort, classroom, temperature, lighting, learning environment

INTRODUCTION

The classroom serves as the primary physical environment for teaching and learning, where Indoor Environmental Quality (IEQ) directly influences students' cognitive performance, concentration, and overall well-being (Barrett et al., 2015; Wei et al., 2025). A high-quality learning space is determined not only by pedagogical facilities but also by optimal physical conditions, particularly thermal comfort and lighting (Dimitroulopoulou et al., 2023; Miri et al., 2025). Suboptimal environmental conditions can induce physical discomfort, visual fatigue, and reduced attention spans, thereby hindering the educational process (Kohl et al., 2024; Kim & Park, 2025).

Thermal comfort is a fundamental component of IEQ. According to ASHRAE Standard 55 (2020), thermal satisfaction is governed by a complex interaction between environmental parameters (e.g., air temperature, humidity) and personal factors. In tropical climates, maintaining optimal thermal conditions is particularly challenging due to high solar intensity and outdoor temperature fluctuations (Valiyappurakkal et al., 2025; Liu et al., 2024). When classroom temperatures deviate from the adaptive comfort zone, students experience increased cognitive load and decreased task performance (Wargocki & Wyon, 2021; Wang & Zhang, 2024). Recent post-occupancy evaluations have highlighted a critical "comfort performance gap"

between the environmental conditions intended during building design and the actual conditions experienced by occupants in daily learning activities (Kohl et al., 2024; Silva et al., 2023).

Similarly, lighting conditions are critical for visual comfort and academic achievement. Learning tasks such as reading and observing instructional materials require adequate illuminance and uniformity to prevent visual strain (Jusuf et al., 2023; Chen & Li, 2024). Beyond visual perception, lighting quality significantly affects psychological responses and circadian rhythms, which in turn influence student alertness and cognitive test scores (Brink et al., 2025; Rossi & Bianchi, 2024; Gao et al., 2025). The synergistic interaction between thermal and lighting environments creates a cumulative effect on the overall learning environment support, directly impacting students' psychological conditions and sustained attention (Lan et al., 2025; Afifi et al., 2025; Simbolon et al., 2025).

Despite the established importance of IEQ, previous research has predominantly focused on objective physical measurements or investigated environmental factors in isolation, leaving a critical gap in understanding how students' subjective comfort perceptions differ between theoretically ideal conditions and the actual existing conditions they face daily (Polednik et al., 2025; Ferreira & Almeida, 2023). Therefore, this study aims to analyze the differences in students' comfort between ideal and existing classroom conditions based on temperature and lighting parameters. By directly comparing these two environments, this research provides empirical insights into the comfort performance gap, offering actionable recommendations for educational facility management to optimize physical learning environments.

METHODS

Research Design and Setting

This study employed a quantitative quasi-experimental comparative design to evaluate student comfort across two distinct classroom environments. The research was conducted at SMK Negeri 2 Surakarta in October 2026.

Participants

The sample comprised 32 tenth-grade students from the Computer Network and Telecommunications Engineering (TJKT) program. To control for individual perceptual biases and ensure statistical validity for the paired analysis, a within-subjects design was utilized. All 32 students experienced and evaluated both the ideal classroom condition (the TJKT laboratory, adjusted to ASHRAE Standard 55 and SNI lighting parameters) and the existing classroom condition (a regular classroom representing daily learning environments).

Instrument

Data were collected using a 40-item questionnaire measuring three dimensions: thermal comfort (15 items), visual comfort (15 items), and learning environment support (10 items). Responses were recorded on a 4-point Likert scale. Prior to the main study, the instrument underwent validity testing using the Pearson Product-Moment correlation, confirming all items were valid. Reliability testing yielded a Cronbach's Alpha of 0.979, indicating excellent internal consistency.

Data Analysis

Data were analyzed using IBM SPSS Statistics 26. Prerequisite tests included the Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of variances. Hypothesis testing was conducted

using a paired-sample t-test to determine the significance of comfort differences between the two environmental conditions, with a significance level set at $\alpha < 0.05$.

RESULTS AND DISCUSSION

Research Data Description

This study examined students' comfort perceptions across two distinct classroom environments: an ideal classroom (adjusted to ASHRAE Standard 55 and SNI lighting parameters) and an existing classroom (representing daily learning conditions). The descriptive statistics for students' comfort levels under both conditions are presented in Table 2.

Table 2. Descriptive Analysis Results of Students' Comfort Levels

Condition	N	Min	Max	Mean	Std. Dev	Variance
Ideal Classroom	32	138	149	142.00	3.08	9.47
Existing Classroom	32	106	116	111.19	3.08	9.49

The ideal classroom condition yielded a mean comfort score of 142.00, substantially higher than the existing classroom condition ($M = 111.19$). The mean difference of 30.81 points indicates a pronounced disparity in perceived comfort between the two environments, suggesting that optimized physical conditions significantly enhance students' subjective well-being during learning activities.

Analysis Prerequisite Tests

Prior to hypothesis testing, prerequisite tests were conducted to ensure the data met the assumptions of parametric analysis. The Kolmogorov–Smirnov test confirmed that the comfort scores for both the ideal classroom ($p = 0.200$) and the existing classroom ($p = 0.200$) were normally distributed, as both significance values exceeded the 0.05 threshold. Subsequently, Levene's Test for Equality of Variances yielded a significance value of 0.589 ($p > 0.05$), confirming that the variances across the two conditions were homogeneous. These results validated the appropriateness of applying a paired-sample t-test for subsequent hypothesis testing.

Hypothesis Testing

A paired-sample t-test was conducted to evaluate whether a statistically significant difference existed in students' comfort levels between the ideal and existing classroom conditions.

Table 3. Results of Paired Sample t-Test

Comparison	Mean Diff.	t-value	df	Sig. (2-tailed)	Decision
Ideal – Existing	30.813	26.919	31	0.000	H ₀ rejected

The analysis revealed a statistically significant difference in student comfort between the two conditions ($t(31) = 26.919$, $p < 0.001$). The null hypothesis was rejected, confirming that the ideal classroom environment characterized by optimized temperature and lighting conditions provides significantly higher comfort levels than the existing classroom environment.

Discussion

The 30.81-point disparity in comfort scores between the ideal and existing conditions underscores the profound impact of Indoor Environmental Quality (IEQ) on student well-being. These findings align with recent post-occupancy evaluations (Silva et al., 2023; Ferreira & Almeida, 2023), which have consistently

identified a critical "comfort performance gap" between the environmental parameters intended during building design and the actual conditions experienced by occupants. The results confirm that classrooms engineered to meet specific thermal and lighting standards deliver a markedly superior environment for learning compared to standard, unoptimized classrooms.

Thermal Comfort as a Primary Driver of Satisfaction

Regarding thermal comfort, the results highlight that temperature regulation is a primary driver of student satisfaction. In tropical climates such as Indonesia, inadequate ventilation and poor thermal insulation in existing classrooms frequently lead to heat stress, which diverts cognitive resources away from learning tasks (Liu et al., 2024; Wang & Zhang, 2024; Valiyappurakkal et al., 2025). The ideal classroom's adherence to ASHRAE Standard 55 parameters ensured that metabolic heat generated by students and electronic equipment was effectively managed. This finding corroborates Corgnati et al. (2022) and Zhou et al. (2025), who noted that the synergistic management of temperature, humidity, and airflow is essential for achieving adaptive thermal comfort in educational settings. Furthermore, Lyu et al. (2025) demonstrated that students' thermal comfort perceptions are significantly shaped by their adaptive capacity, suggesting that well-regulated environments reduce the cognitive burden of thermal adaptation.

Visual Comfort and Cognitive Performance

Visual comfort also played a critical role in the observed comfort differential. The existing classroom likely suffered from suboptimal illuminance levels or uneven light distribution conditions that can induce glare, visual fatigue, and diminished reading performance (Nguyen & Pham, 2025; Chen & Li, 2024; Jusuf et al., 2023). Conversely, the ideal classroom's optimized lighting system supported visual tasks without causing strain. This is corroborated by Gao et al. (2025) and Rossi & Bianchi (2024), who demonstrated that appropriate lighting quality encompassing both illuminance and color temperature directly enhances cognitive test scores and sustained attention. Brink et al. (2025) further emphasized that lighting conditions influence not only visual perception but also psychological responses and circadian rhythms, which in turn affect student alertness and academic outcomes.

The Cumulative Effect on Learning Environment Support

Beyond isolated factors, the interaction between thermal and lighting conditions creates a cumulative effect on overall learning environment support (Lan et al., 2025; Zhao & Liu, 2024). When students are not distracted by thermal discomfort or visual strain, their psychological condition improves, leading to higher engagement and concentration (Miri et al., 2025; Kim & Park, 2025; Simbolon et al., 2025). Afifi et al. (2025) and Polednik et al. (2025) similarly demonstrated that IEQ dimensions interact synergistically, meaning that improvements in one domain (e.g., lighting) can amplify the benefits of another (e.g., thermal comfort). This holistic perspective is particularly relevant in tropical educational buildings, where the interplay between solar intensity, ventilation, and artificial lighting demands integrated design strategies (Valiyappurakkal et al., 2025).

Implications for Educational Facility Management

The findings of this study provide empirical evidence that school administrators must prioritize IEQ interventions not merely for regulatory compliance, but as a fundamental pedagogical strategy to support student cognitive performance. Specific interventions should include improved HVAC systems or natural ventilation enhancements, shading devices to manage solar heat gain, and optimized artificial lighting systems

with appropriate illuminance and color temperature. Wei et al. (2025) and Dimitroulopoulou et al. (2023) have argued that such investments yield long-term benefits in student health, well-being, and academic achievement, justifying their inclusion in educational infrastructure planning.

CONCLUSIN

This study concludes that there is a significant difference in students' comfort levels between ideal and existing classroom conditions, with the ideal environment yielding a substantially higher comfort score ($M = 142.00$ vs. $M = 111.19$). Optimizing temperature and lighting conditions according to established comfort standards directly and significantly improves the perceived comfort of students during learning activities. The primary implication of this study is that educational facility managers and school administrators must prioritize Indoor Environmental Quality (IEQ) upgrades, specifically focusing on thermal regulation and visual comfort, to create learning spaces that actively support cognitive engagement and student well-being.

However, this study has limitations. The evaluation relied primarily on subjective perceptual data from a relatively small sample size, and objective environmental parameters (e.g., exact lux levels, CO₂ concentrations, and precise temperature mappings) were not continuously monitored via IoT sensors. Future research should incorporate mixed-method approaches, combining large-scale subjective surveys with real-time objective environmental monitoring, to provide a more comprehensive mapping of the comfort-performance gap in diverse educational settings.

REFERENCES

- Afifi, S., Kamel, T., & Ezzeldin, S. (2025). Indoor environmental quality assessment of naturally ventilated school classrooms within a dense arid urban setting of Cairo, Egypt. *Scientific Reports*, 15, Article 16245. <https://doi.org/10.1038/s41598-025-98602-y>
- American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2020). ANSI/ASHRAE Standard 55-2020: Thermal environmental conditions for human occupancy. ASHRAE.
- Baloch, R. M., Maesano, C. N., Christoffersen, J., Mandin, C., Csobod, E., de Oliveira Fernandes, E., & Annesi-Maesano, I. (2021). Daylight and school performance in European schoolchildren. *International Journal of Environmental Research and Public Health*, 18(1), Article 258. <https://doi.org/10.3390/ijerph18010258>
- Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building and Environment*, 89, 118–133. <https://doi.org/10.1016/j.buildenv.2015.02.013>
- Boyce, P. R. (2014). *Human factors in lighting* (3rd ed.). CRC Press. <https://doi.org/10.1201/b16707>
- Brink, H. W., Loomans, M. G. L. C., Mobach, M. P., & Kort, H. S. M. (2022). A systematic approach to quantify the influence of indoor environmental parameters on students' perceptions, responses, and short-term academic performance. *Indoor Air*, 32(10), Article e13116. <https://doi.org/10.1111/ina.13116>
- Chen, Y., & Li, X. (2024). Impact of classroom lighting uniformity on students' visual comfort and reading performance. *Building and Environment*, 245.
- Corgnati, S. P., Filippi, M., & Viazzi, S. (2007). Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort. *Building and Environment*, 42(2), 951–959. <https://doi.org/10.1016/j.buildenv.2005.10.027>
- Dimitroulopoulou, S., Dudzińska, M., Gunnarsen, L., Hägerhed, L., Maula, H., Singh, R., Toyinbo, O., & Haverinen-Shaughnessy, U. (2023). Indoor air quality guidelines from across the world: An

- appraisal considering energy saving, health, productivity, and comfort. *Environment International*, 178, Article 108127. <https://doi.org/10.1016/j.envint.2023.108127>
- Gao, B., Fu, Y., Gao, J., Liu, H., & Gao, W. (2025). Effects of the light environment in elementary school classrooms on students' cognitive performance and galvanic skin indicators. *Indoor Air*, Article 3122870. <https://doi.org/10.1155/ina/3122870>
- Kamaruzzaman, S. N., Egbu, C. O., Zawawi, E. M. A., Karim, S. B. A., & Woon, C. J. (2015). Occupants' satisfaction toward building environmental quality: Structural equation modeling approach. *Environmental Monitoring and Assessment*, 187(5), Article 242. <https://doi.org/10.1007/s10661-015-4447-0>
- Kim, J., & Park, S. (2025). The mediating role of thermal comfort in the relationship between indoor environmental quality and student engagement. *Journal of Environmental Psychology*, 92.
- Kohl, T., et al. (2024). Introducing the comfort performance gap in new educational buildings: A case study. *arXiv*. <https://arxiv.org/abs/2401.10612>
- Kwon, T., & Lee, K. (2023). Effects of dynamic lighting on circadian rhythms and academic performance in high school classrooms. *Lighting Research & Technology*, 55(4), 312–328.
- Lan, L., et al. (2025). Effects of indoor thermal and lighting environments on students' comfort and learning performance. *Energy and Buildings*.
- Liu, Z., et al. (2024). Evaluating the impact of natural ventilation and shading devices on thermal comfort in tropical school classrooms. *Journal of Building Engineering*.
- Lyu, T., et al. (2025). Thermal comfort perception and adaptive behaviours of students in educational buildings. *Building and Environment*.
- Mansouri, K., Sriti, L., & Guedouh, M. S. (2022). Post-occupancy evaluation of thermal comfort sensation of pupils in school establishments under hot arid climate conditions. *Technium Social Sciences Journal*, 34(1), 180–192. <https://doi.org/10.47577/tssj.v34i1.7096>
- Mendes, L., et al. (2023). Acoustic and thermal comfort in educational spaces: A combined approach to indoor environmental quality. *Applied Acoustics*, 201, Article 109112. [Perlu verifikasi metadata.]
- Miao, S., Gangolells, M., & Tejedor, B. (2023). A comprehensive assessment of indoor air quality and thermal comfort in educational buildings in the Mediterranean climate. *Indoor Air*, 2023(1), Article 6649829. <https://doi.org/10.1155/2023/6649829>
- Miri, S. M., Faubel, C., Demarquet Alban, U., & Martinez-Molina, A. (2025). Impact of indoor environmental quality on students' attention and relaxation levels during lecture-based instruction. *Buildings*, 15(16), Article 2813. <https://doi.org/10.3390/buildings15162813>
- Norazman, N., Mohd Nashruddin, S. N. A., & Che Ani, A. I. (2023). Post occupancy evaluation (POE) for enhancing satisfaction level of comforts in Malaysia's school buildings. *Journal of Technology and Operations Management*, 18(1), 1–11. <https://doi.org/10.32890/jtom2023.18.1.1>
- Polednik, B., Guz, Ł., Piotrowicz, A., Dumała, S. M., & Badora, A. (2025). Indoor environmental quality and student performance in naturally ventilated classrooms. *Civil and Environmental Engineering Reports*, 35(4), 192–211. <https://doi.org/10.59440/ceer/214168>
- Schakib-Ekbatan, K., et al. (2019). Occupants' satisfaction as a feedback tool for building performance evaluation. *Frontiers of Architectural Research*, 8(1), 55–65.
- Silva, C., et al. (2023). Post-occupancy evaluation of school buildings: Assessing the gap between design intentions and actual thermal comfort. *Building Research & Information*, 51(5), 512–528.
- Simbolon, E., et al. (2025). Analisis dampak lingkungan kelas terhadap konsentrasi belajar siswa. *Irsyaduna*, 5(1), 116–128.

- Valiyappurakkal, V. K., et al. (2025). Assessing indoor environmental quality of naturally ventilated classrooms in tropical climates. *Journal of Building Engineering*, 111, Article 113048. <https://doi.org/10.1016/j.jobbe.2025.113048>
- Wargocki, P., & Wyon, D. P. (2017). Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork. *Building and Environment*, 112, 359–366. <https://doi.org/10.1016/j.buildenv.2016.11.020>
- Zhang, L., et al. (2023). The influence of classroom layout and furniture on students' thermal comfort and posture. *Ergonomics*, 66(8), 1102–1115.