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Computational studies: A passive strategy to improve visual comfort by optimizing daylight uniformity in the classroom

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ABSTRACT

Even distribution of natural light is crucial in creating optimal visual comfort in classrooms. Many classrooms in tropical areas experience lighting imbalances, with areas near windows receiving excessive light, while others lack lighting. This study aims to evaluate the effectiveness of passive design strategies in improving the uniformity of natural lighting through a computational simulation approach. The research subjects include elementary, junior high, and senior high school classrooms in Makassar City, South Sulawesi. Modeling was conducted using Ecotect Analysis 2010 software, comparing two types of spaces: existing models and models with passive design interventions such as reflective floors. Simulation results show that passive design can improve daylight uniformity and significantly reduce glare potential. In addition to supporting visual comfort, the application of this strategy also contributes to energy efficiency by reducing dependence on artificial lighting. This study recommends the application of passive design as an integral part of sustainable classroom planning, especially in tropical climates.

Introduction

Natural lighting plays a vital role in creating learning environments that support students' productivity and well-being. Recent studies have shown that optimal natural lighting contributes to improved focus, eye health, mood, and visual comfort for students in classrooms (Lekan-Kehinde and Asojo 2021). Moreover, the presence of natural light directly influences the human circadian rhythm and visual system, which in turn affects occupants' performance and health (Shishegar and Boubekri 2016). Research also indicates that the quality of natural lighting is positively correlated with student motivation, teacher job satisfaction, and reduced absenteeism (Issa et al. 2011).

However, many classrooms, particularly in tropical regions, face challenges in achieving uniform distribution of natural light. This is often due to architectural designs that fail to adequately consider the building's orientation, the size and placement of openings, and the presence of shading devices (Heidari et al. 2021). An imbalance in lighting distribution can result in some areas being excessively illuminated while others are underlit. This irregularity not only diminishes visual comfort but also increases the risk of eye strain and the excessive use of artificial lighting (Kieu et al. 2024).

Visual comfort in educational settings is crucial, as it has a direct impact on cognition and student engagement in the learning process. A high level of daylight uniformity has been shown to reduce glare, enhance the visual quality of the space, and promote cognitive performance among students (Tunahan et al. 2022; Idrus et al. 2020). Furthermore, younger children are known to be more sensitive to variations in lighting compared to older students, making consistent lighting an essential supporting factor in their learning process (Yunitsyna and Toska 2023).

According to SNI 03-6197-2000, classrooms should have an average natural illuminance of at least 250 Lux. Meanwhile, SNI 03-6575-2001 emphasizes the importance of even light distribution to support visual comfort. Field studies have revealed that minimum illumination standards alone are insufficient to ensure visual comfort. Such comfort depends on the even distribution of light, the quality of the lighting, and the potential for glare within the space (Idrus et al. 2020; Leslie et al. 2012). Classrooms that do not meet uniformity standards in lighting have the potential to create uncomfortable zones that interfere with students' learning activities.

To address these challenges, passive design approaches offer effective and sustainable solutions. Strategies such as the use of fixed shading devices, bilateral asymmetric openings, and the integration of reflective elements such as light shelves have proven effective in improving the quality and uniformity of natural light distribution (Atthaillah et al. 2023). Building orientation also plays a crucial role in maximizing natural lighting potential while avoiding excessive heat gain (Cillari et al. 2021). Through such configurations, natural lighting can serve as a primary solution for creating healthy and efficient learning spaces.

Beyond visual benefits, passive design also supports significant energy efficiency. Studies show that passive interventions such as daylight-responsive lighting control systems can save up to 46% in lighting energy consumption (Tırmıkçı and Yavuz 2020). The implementation of devices such as louvers and light shelves can reduce energy use by as much as 80% (Kieu et al. 2024). These findings underscore the importance of integrating natural lighting strategies as part of energy-saving efforts in educational buildings (Phương et al. 2023).

In designing environmentally friendly and energy-efficient classrooms, the use of computational simulation becomes a critical design tool. Simulation technology allows architects and designers to evaluate various design scenarios virtually before actual implementation. Software such as Ecotect Analysis, Radiance, and other parametric systems has been employed to assess natural lighting performance, energy efficiency, and environmental impact in a holistic manner (Ratajczak et al. 2023). This approach enhances design accuracy and supports data-driven decision-making.

Furthermore, the integration of generative approaches and multi-objective optimization in simulations enables the exploration of multiple design alternatives that simultaneously consider performance, visual comfort, and energy efficiency (Foged 2024). This allows for the attainment of optimal design solutions from the early stages of the design process, while minimizing the risk of inefficient designs during construction and operational phases (Schwartz et al. 2021).

Based on this theoretical foundation and empirical findings, the present study aims to analyze passive design strategies that can optimize the distribution of natural light in classrooms through a computational simulation approach. The study is contextualized in a tropical climate classroom in the city of Makassar and covers three educational levels: Elementary School, Junior High School, and Senior High School. By evaluating the lighting performance of various passive design configurations, this research is expected to provide concrete recommendations for designers in creating classrooms that support visual comfort, energy efficiency, and environmental sustainability.

Methods

Research object and classroom modeling

This study focuses on the analysis of sunlight performance and visual comfort in standard classrooms across three educational levels: elementary school, junior high school, and senior high school in Makassar, Indonesia. The selected classrooms represent the typology of public schools that adhere to the national spatial standards for classroom dimensions and structural elements.

Figure 1. Classroom of SD Negeri Unggulan Toddopuli elementary school

Figure 2. Classroom of SMP Negeri 33 Makassar junior high school

Each educational level was modeled based on standard spatial configurations. The elementary school classroom measures 7.5 meters in length and 7 meters in width, with a ceiling height of 3 meters. A visualization of the elementary school's classroom is presented in figure 1. The corridor adjacent to the classroom is shaded by a roof canopy 2 meters in height, along with an additional rear canopy extending 80 cm. Two orientation scenarios were tested: East–West (E–W) and North–South (N–S). Two model types were developed for each scenario: Type 1 Model represents the existing condition with a total window opening area of 18.36 m², while Type 2 Model incorporates passive design strategies using the same total glazing area.

The junior high school classroom was modeled with dimensions of 9 meters in length and 7 meters in width, while the senior high school classroom measures 9 meters in length and 8 meters in width. Visualizations of the school's classrooms are presented in figures 2 and 3. Both models maintain a ceiling height of 3 meters and include similar canopy features.

In each case, the Type 1 Model serves as the baseline representation of current conditions, while the Type 2 Model integrates passive modifications such as light shelves and adjusted window placement, while maintaining a consistent window-to-floor ratio (WFR).

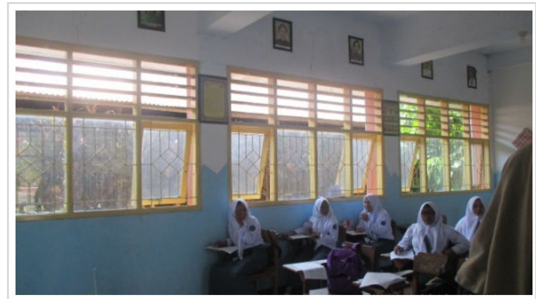

Figure 3. Classroom of SMA Negeri 21 Makassar senior high school

Simulation tools and procedure

Daylight simulation was conducted using *Autodesk Ecotect Analysis 2010*, a validated simulation tool known for its compatibility with tropical climate modeling and its proven capability in assessing daylight performance in educational environments (Yang and Kim 2024). The pre-simulation setup involved the following parameters:

a. Simulation Time – To obtain optimal modeling outcomes, various classroom lighting designs were analyzed at the same time frame: August 5 at 12:00 PM.
b. Weather File – To ensure that simulation results closely reflect local conditions, a weather file with the *wea* extension specific to Makassar was used.
c. Design Sky Illuminance – A planning sky illuminance of 10,000 Lux was adopted, in accordance with Indonesian National Standard (SNI) guidelines.
d. Sky Condition Model – The CIE Overcast Sky Condition model (default in Ecotect) was employed for consistency and comparability.
e. Window Cleanliness – The cleanliness of windows was set to "Average" to represent typical school maintenance conditions.
f. Sensor Height – The measurement plane was established at the standard working plane height of 0.75 meters from the floor.
g. Analysis Grid Setup – The daylight analysis grid was automatically generated using the "Auto-Fit Grid to Object" option to ensure accurate spatial sampling.

These simulation parameters were applied consistently across all typologies and model variations to support comparative analysis.

Assessment of daylight performance

Daylight performance was assessed using both quantitative metrics and visual analysis. The primary metric for evaluating visual comfort was Daylight Uniformity, expressed as the ratio of minimum to maximum illuminance (Emin/Emax). According to Mathalamuthu et al. (2018), a uniformity ratio ≥0.5 is considered acceptable, while ≥0.7 is preferred for optimal comfort. This benchmark was adopted due to its application in classroom settings across Malaysia and Southeast Asia, which share similar climatic conditions with Indonesia.

To assess lighting adequacy, the simulation results were benchmarked against SNI 03-6197-2000, which stipulates a minimum average illuminance of 250 Lux for educational spaces. Both average and point-based measurements were analyzed for each grid cell within the classroom model.

A visual inspection of daylight distribution was conducted through isometric light level mapping in Ecotect. This output facilitated the validation of spatial consistency, identification of glare-prone zones, and evaluation of daylight penetration depth thereby supporting a holistic interpretation of numerical results (Mukhtar et al. 2024).

Consideration of passive design features

The Type 2 Models incorporated the following passive design interventions:

- Reflective Light Shelves installed at a height of 1 meter on the window-facing wall, with a width of 1.1 meters, aimed at redirecting sunlight deeper into the classroom interior (Bahdad et al. 2022).
- Asymmetrical Window Placement to enhance daylight diffusion and minimize contrast between illuminated and shaded areas (Atthaillah et al. 2023).
- Adjustment of Classroom Orientation, where applicable, to examine how alignment with the solar path influences daylight quality (Cillari et al. 2021).

These features were selected based on literature identifying their effectiveness in improving daylight penetration and uniformity, particularly within tropical educational settings (Kustiawan et al. 2023).

Glare evaluation methods

Given students' sensitivity to excessive brightness and visual discomfort, glare analysis was incorporated using the Daylight Glare Probability (DGP) metric, alongside observational assessment of high-illuminance zones exceeding 1,000 Lux. DGP was selected for its precision in predicting glare-related discomfort based on luminance contrast, and its reliability has been validated in recent studies of glare within classroom environments (Viula et al. 2023).

Results and discussion

Type-1 Elementary school classroom model (Existing condition)

The simulation results for the Type-1 elementary school classroom model (table 1), which represents the existing standard configuration with a total window area of 18.36 m², indicate that although the average illuminance levels for both the North–South (N/S) and East–West (E/W) orientations exceed the minimum required threshold of 250 Lux (Eavg: 723.88 Lux for 1A; 626.08 Lux for 1B), the daylight uniformity remains suboptimal. The uniformity ratios (Emin/Emax) for models 1A and 1B are 0.3 and 0.4, respectively both falling below the acceptable threshold of 0.5 (Mathalamuthu et al. 2018).

Table 1. Analysis of daylighting in Type-1 elementary school classroom

Model	Orientation	Window area (m²)	Floor area (m²)	WFR (Window-to-Floor Ratio)	Emin (Lux)	Emax (Lux)	Eavg (Lux)
1A	E/W	18,36	52,5	34,97%	450	1450	723,88
1B	N/S	18,36	52,5	34,97%	400	1000	626,08

Model	Eavg	Emin: Emax	Light quantity	Uniformity
			Evg >=250 Lux	Emin: Emax >=0,5
1A	723,88	0,3	Meets	Does not meet
1B	626,08	0,4	Meets	Does not meet

The low uniformity values indicate the presence of an intense lighting gradient throughout the room, which may lead to visual discomfort due to glare, particularly in areas that receive excessive sunlight. In this case, the simulation visuals confirm that some areas of the classroom exceed 1,000 Lux, indicating a potential risk of glare (figures 4 and 5). This condition could negatively affect students' focus and learning retention, especially among younger students, who are more sensitive to lighting conditions (Canlı et al. 2024).

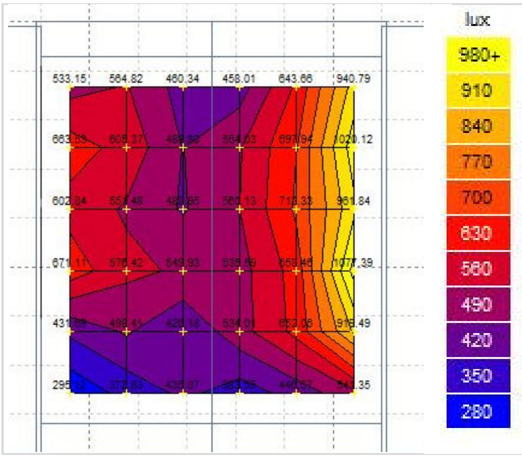

Figure 4. Analysis of daylighting in Type-1A elementary school classroom (E/W orientation)

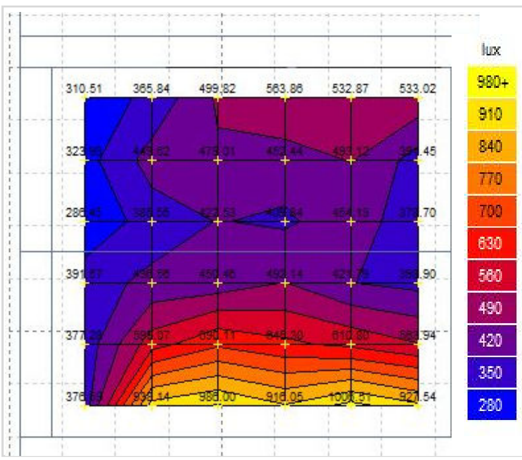

Figure 5. Analysis of daylighting in Type-1B elementary school classroom (N/S orientation)

In addition, the presence of overly bright zones in the East-West oriented classroom (1A: Emax = 1,450 Lux) underscores the limitations of placing windows symmetrically without incorporating reflective elements or diffusers. According to Viula et al. (2023), illuminance values exceeding 1,000 Lux are strongly associated with discomfort from glare, highlighting the importance of assessing glare metrics such as Daylight Glare Probability (DGP) and Unified Glare Rating (UGR) in future evaluations. DGP is a more accurate predictor of glare under dynamic daylight conditions in tropical classrooms compared to UGR (Karmann et al. 2022).

Type-2 classroom model (Integration of passive design)

The modified Type-2 classroom model introduces passive lighting strategies, including the incorporation of a reflective floor surface 1.1 meters wide on one side and slight adjustments to window elevation, while maintaining the same window-to-floor ratio. The results demonstrate a significant improvement in average illuminance (2A: 496.64 Lux; 2B: 502.72 Lux) and daylight uniformity (0.5 and 0.7, respectively), as seen in table 2. These modifications help create a more balanced distribution of natural light, reducing glare and enhancing the overall visual comfort within the classroom environment.

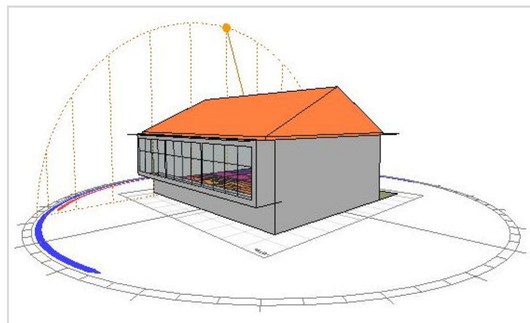

Figure 6. Modeling of Type-2 elementary school classroom using ecotect

Table 2. Analysis of daylighting in Type-2 elementary school classroom

Model	Orientation	Opening area (m2)	Floor area (m2)	WFR	Emin	Emax	Eavg
2A	E/W	18,36	52,5	34,97%	350	650	496,64
2B	N/S	18,36	52,5	34,97%	400	600	502,72

Model	Eavg	Emin: Emax	Light quantity	Uniformity
			Evg >=250 Lux	Emin: Emax >=0,5
2A	496,64	0,5	Meets	Does not meet
2B	502,72	0,7	Meets	Does not meet

This result is consistent with the findings of Bahdad et al. (2022), who observed that the integration of light shelves can enhance the uniformity and penetration of daylight in classrooms by reducing contrast and expanding sunlight distribution (figures 7 and 8). The increased uniformity in model 2B (N/S orientation) indicates superior sunlight diffusion, reducing glare potential and visual fatigue. The peak illuminance values (Emax: 650 Lux for 2A; 600 Lux for 2B) are within the recommended threshold, indicating effective mitigation of excessive light intensity, thereby reducing glare potential.

This improvement not only benefits visual comfort but also has the potential to enhance academic performance, as consistent lighting levels correlate with better student focus and reduced distraction (Ackley et al. 2020). Furthermore, classrooms with well-managed daylight distribution contribute to energy savings by reducing the need for artificial lighting, supporting the findings of Atthaillah et al. (2023).

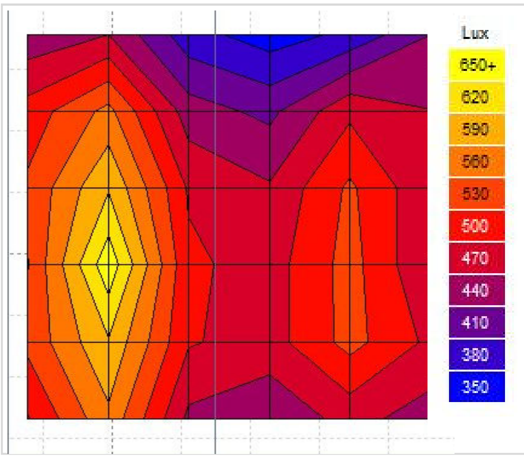

Figure 7. Analysis of daylight in primary school classroom Type-2A (E/W orientation)

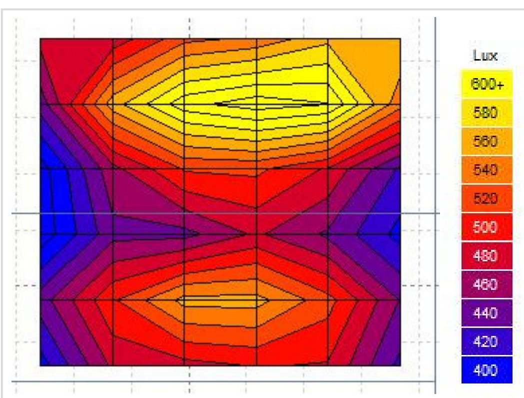

Figure 8. Analysis of daylight in primary school classroom Type-2B (N/S)

Type-1 Junior high school classroom model (existing condition)

The simulation for the Junior High School (SMP) Classroom Type-1 with a window area of 22.14 m² shows high average illuminance values (743.71 Lux for model 1A and 716.76 Lux for model 1B), confirming compliance with the SNI 03-6197-2000 standard (see table 3). However, similar to the Primary School (SD) base model, the uniformity ratios are 0.3 (1A) and 0.4 (1B), which do not meet the minimum recommended daylight uniformity level.

Table 3. Analysis of daylighting in Type-1 junior high school classroom

Model	Orientation	Window area (m2)	Floor area (m2)	WFR	Emin	Emax	Eavg
1A	E/W	22,14	63	35,14%	450	1450	743,71
1B	N/S	22,14	63	35,14%	480	1180	716,76

Model	Eavg	Emin: Emax	Light quantity Evg >=250 Lux	Uniformity Emin: Emax >=0,5
1A	743,71	0,3	Meets	Does not meet
1B	716,76	0,4	Meets	Does not meet

The high Emax values (1,450 Lux and 1,180 Lux, respectively) raise concerns about the potential for glare and student discomfort. These values indicate an uneven light distribution, possibly caused by the asymmetrical window positioning and the absence of a sun light diffusion strategy. This finding aligns with the literature, which notes that symmetric window designs often result in unbalanced sunlight penetration, particularly in tropical classroom configurations (Mirrahimi et al. 2022).

It is also important to note that the difference between the N/S and E/W orientations has minimal impact on uniformity results in the initial configuration, although the N/S orientation offers a slightly lower Emax value. This suggests the need for further exploration into the effects of sunlight paths and facade orientation in optimizing sunlight in classrooms, in line with orientation studies by Litardo et al. (2021).

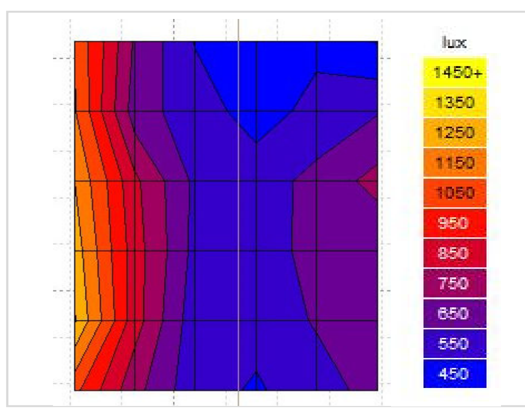

Figure 9. Analysis of daylight in junior high school classroom Type-1A (E/W orientation)

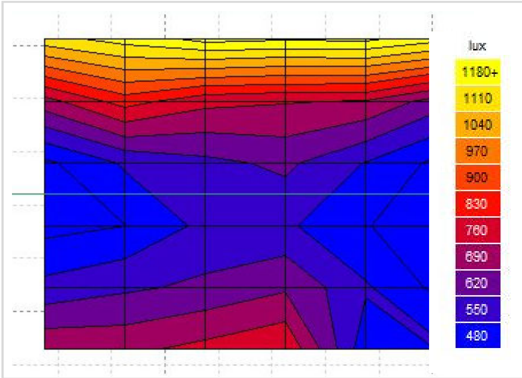

Figure 10. Analysis of daylight in junior high school classroom Type-1B (N/S orientation)

Visually, the simulation results show uneven light intensity (figures 9 and 10). On one side of the room, the lighting illumination exceeds 1,000 Lux.

The Type-2 junior high school classroom model (Integration of passive design)

After integrating passive elements such as reflective surfaces and optimized window configurations into the Type-2 Junior High School classroom model, lighting performance significantly improved. Models 2A and 2B recorded average illumination values above 500 Lux, with daylight uniformity ratios of 0.7 and 0.5, respectively, meeting the standards for both quantity and quality of classroom lighting (table 4).

The reduced Emax values (600 Lux for 2A and 650 Lux for 2B) further demonstrate the passive design's ability to limit glare, enhancing the visual comfort of the occupants. As highlighted by Ploycharoen et al. (2024), parametric simulation methods, such as those employed in this study, provide detailed insights into how passive design strategies influence spatial daylight performance across seasons. Visual evidence from the simulation renderings reinforces this conclusion, showing more uniform light distribution throughout the classroom interior, especially in layouts oriented with the N/S configuration.

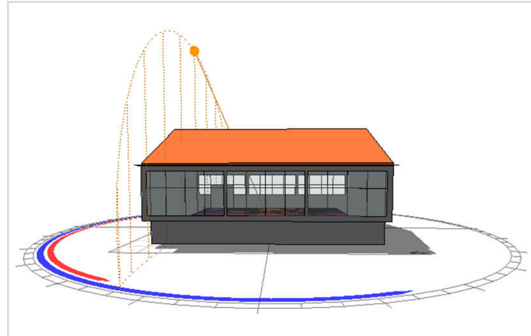

Figure 11. Modeling of Type-2 junior high school classroom using ecotect

Table 4. Analysis of daylighting in Type-2 junior high school classroom

Model	Orientation	Window area (m2)	Floor area (m2)	WFR	Emin	Emax	Eavg
2A	E/W	22,14	63	35,14%	400	600	511,97
2B	N/S	22,14	63	35,14%	350	650	508,06

Model	Eavg	Emin: Emax	Light quantity	Uniformity
			Evg >=250 Lux	Emin: Emax >=0,5
2A	511,97	0,7	Meets	Meets
2B	508,06	0,5	Meets	Meets

In terms of energy performance, the optimized daylighting configuration in the Type-2 classroom can contribute to a 40–60% reduction in artificial lighting demand, consistent with the energy savings reported in Nur et al. (2022). This highlights the potential scalability of this strategy across similar educational facilities throughout Southeast Asia.

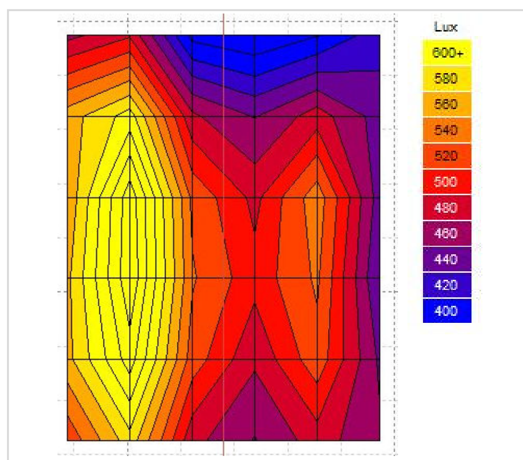

Figure 12. Analysis of daylight in junior high school classroom Type-2A (E/W orientation)

Visually, the simulation results show a uniform light intensity distribution (figures 12 and 13).

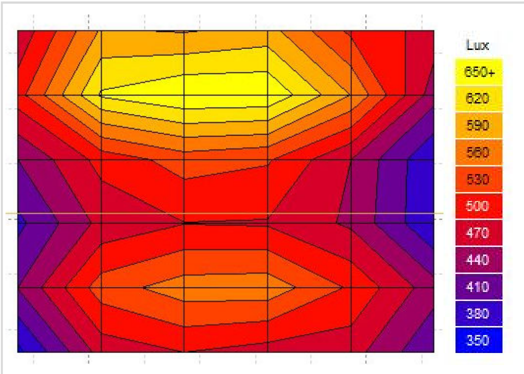

Figure 13. Analysis of daylight in junior high school classroom Type-2B (N/S orientation)

Type-1 Senior high school classroom model (Existing condition)

In the Type-1 configuration for senior high school classrooms, which adopts the standard classroom model with a window area of 22.14 m², both North-South (N/S) and East-West (E/W) orientations yield average illumination levels exceeding the 250 Lux standard (Eavg: 657.22 Lux for 1A; 666.82 Lux for 1B), as presented in table 5. However, as observed in other Type-1 models, the daylight uniformity ratio remains suboptimal (0.3 for both orientations), falling below the recommended minimum threshold of 0.5 (Mathalamuthu et al. 2018).

Table 5. Analysis of daylighting in Type-1 senior high school classroom

Model	Orientation	Window area (m2)	Floor area (m2)	WFR	Emin	Emax	Eavg
1A	E/W	22,14	72	30,75%	360	1360	657,22
1B	N/S	22,14	72	30,75%	400	1400	666,82

Model	Eavg	Emin: Emax	Light quantity Evg >=250 Lux	Uniformity Emin: Emax >=0,5
1A	657,22	0,3	Meets	Does not meet
1B	666,82	0,3	Meets	Does not meet

The high maximum illumination levels 1,360 Lux for 1A and 1,400 Lux for 1B indicate concentrated zones of excessive brightness, raising significant concerns regarding uncomfortable glare. In line with Faraji et al. (2023), these findings suggest a risk of visual strain that can hinder concentration and comfort, particularly during prolonged learning sessions. Although the Unified Glare Rating (UGR) metric has been widely used, its limitations under tropical daylighting conditions are evident. Incorporating the Daylight Glare Probability (DGP) metric in future evaluations would enhance predictive accuracy, especially under the dynamic solar paths and high solar altitudes characteristic of equatorial settings (Karmann et al. 2022).

These results underscore the limitations of symmetric window design in classrooms without the support of passive design interventions. The consistently poor daylight uniformity performance across all Type-1 classrooms reinforces the need for adaptive design strategies that better distribute and diffuse natural light.

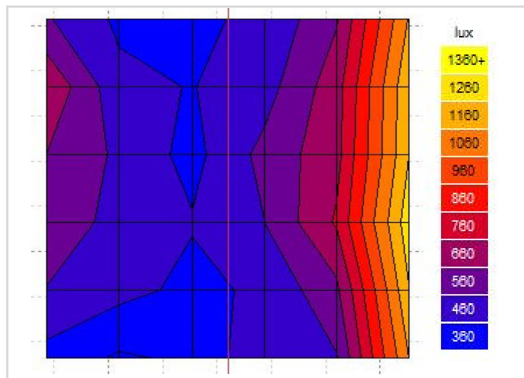

Figure 14. Analysis of daylight in senior high school classroom Type-1A (E/W orientation)

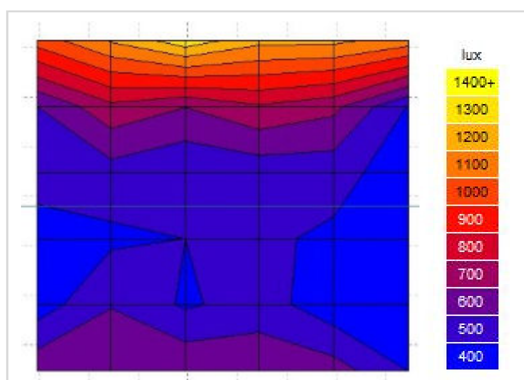

Figure 15. Analysis of daylight in senior high school classroom Type-1B (N/S orientation)

Visually, the simulation results reveal uneven light intensity distribution (figures 14 and 15). On one side of the room, illumination levels exceed 1,000 Lux.

Type-2 Senior high school classroom model (Integration of passive design)

The introduction of passive lighting strategies in the Type-2 senior high school classroom model led to a marked improvement in both the quantitative and qualitative aspects of lighting performance. Classrooms with modified configurations featuring reflective surfaces and enhanced spatial orientation achieved Eavg values of 494.56 Lux (2A) and 547.32 Lux (2B), comfortably exceeding the required standards. More importantly, the daylight uniformity ratios increased significantly to 0.5 and 0.6, respectively (table 6), indicating compliance with recommended daylight distribution parameters.

The Emax values of 620 Lux (2A) and 700 Lux (2B) confirm that no areas within the classroom are excessively bright, thereby reducing the risk of glare. These findings are consistent with the study by Alegbe et al. (2023), which supports the effectiveness of passive interventions in regulating daylight exposure and minimizing user-reported glare. Further visual simulations confirm uniform light distribution in both orientations, indicating improved visual comfort throughout the learning space.

Table 6. Analysis of daylighting in Type-2 senior high school classroom

Model	Orientation	Window area (m2)	Floor area (m2)	WFR	Emin	Emax	Eavg
2A	N/S	22,14	72	30,75%	320	620	494,56
2B	E/W	22,14	72	30,75%	400	700	547,32

Model	Eavg	Emin: Emax	Light quantity Evg >=250 Lux	Uniformity Emin: Emax >=0,5
2A	494,56	0,5	Meets	Meets
2B	547,32	0,6	Meets	Meets

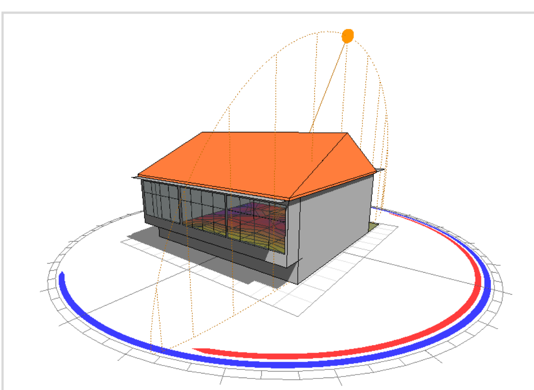

Figure 16. Modeling of Type-2 senior high school classroom using ecotect

Moreover, these improvements have broader implications. Better daylight uniformity is linked to enhanced cognitive focus and long-term academic performance across student age groups (Kunduracı and Kızılörenli 2024). These findings strengthen the argument that natural lighting strategies are not merely an architectural enhancement but also an integral part of the pedagogical quality of the educational environment.

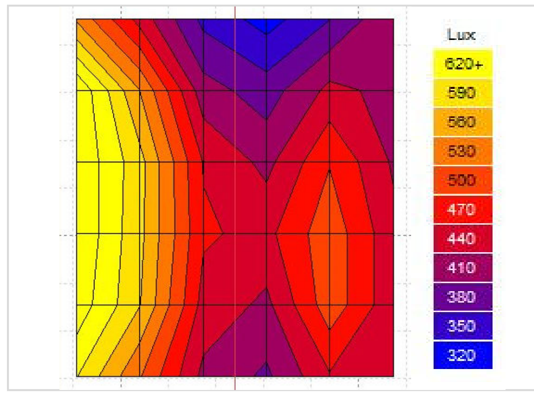

Figure 17. Analysis of daylight in senior high school classroom Type-2A (E/W orientation)

Visually, it can be seen from the simulation results that the light intensity is even (figures 17 and 18).

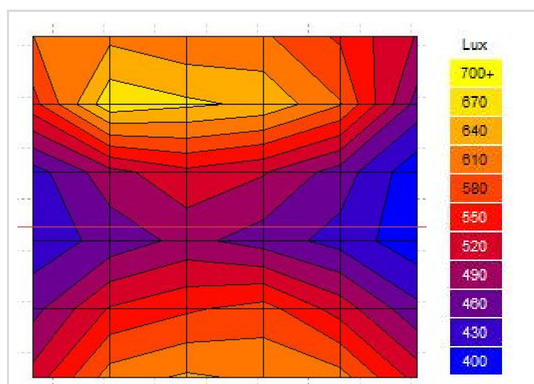

Figure 18. Analysis of daylight in senior high school classroom Type-2B (N/S orientation)

Cross-education level comparative analysis

Across all three educational levels (Elementary School, Junior High School, Senior High School), a consistent pattern emerges. The Type-1 model, representing the existing classroom design, meets the minimum lighting requirements but falls short in achieving acceptable daylight uniformity. In contrast, the

Type-2 model, which implements passive lighting strategies such as reflective flooring and strategic window redesign demonstrates a substantial improvement in both Eavg metrics and daylight uniformity.

Figure 19. The 3D image of the passive design of the classroom building

The image-based simulation rendering consistently shows smoother light gradients and fewer glare points on the Type-2 model. This result is supported by contemporary research highlighting the dual benefits of passive natural lighting in terms of visual comfort and lighting energy reduction (Nur et al. 2022). Additionally, the simulation validates that this strategy can be scaled and replicated across various dimensions and classroom layouts.

From an energy efficiency perspective, the enhanced daylight performance in the Type-2 model suggests significant potential for reducing electrical lighting loads during the day. Studies estimate that optimized daylighting in schools across Southeast Asia could result in energy savings of up to 60% (Mandala et al. 2021). Moreover, by reducing reliance on artificial lighting, this intervention contributes to long-term sustainability and operational cost savings.

Effect of orientation on natural lighting outcomes

Orientation is a key factor in natural lighting performance, particularly in humid tropical regions where the sun's position remains relatively stable throughout the year. This study indicates that classrooms oriented North-South tend to yield better light uniformity and lower Emax values across educational levels.

These findings are consistent with research by Iqbal et al. (2023), which emphasizes the visual and thermal advantages of such orientations. Implementing adaptive shading devices based on orientation could serve as a significant next step in optimizing visual comfort and managing seasonal variability.

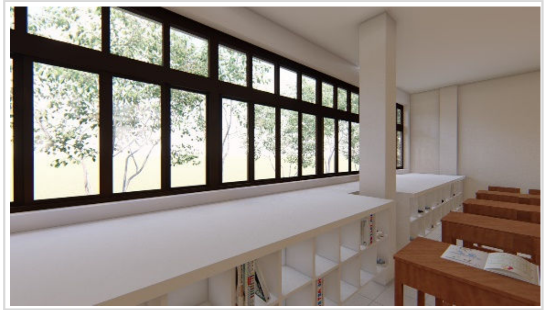

Figure 20. Reflective flooring in classroom interiors as a passive design

Conclusions

This study demonstrates that passive design strategies can significantly enhance visual comfort in classrooms by optimizing the distribution of natural lighting. Simulations conducted at three educational levels in Makassar City revealed that the existing classroom model (Type 1), while meeting minimum illumination standards, failed to provide uniform light distribution and posed a risk of glare. In contrast, the implementation of passive design in the Type 2 model, through the addition of reflective surfaces and orientation adjustments, successfully improved daylight uniformity and reduced the maximum illumination value to a range that is comfortable for learning activities.

The achievement of better daylight uniformity in the Type 2 model not only supports visual comfort but also has the potential to improve student focus and productivity, as well as reduce the need for artificial lighting. This indicates that classroom design that incorporates passive design principles is not only relevant in terms of user comfort but also essential for energy efficiency and environmental sustainability. Therefore, this study recommends the integration of passive design strategies in the planning of educational spaces, particularly in tropical climates, as a strategic step toward creating healthy, energy-efficient learning environments that support academic achievement.

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Irnawaty Idrus contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Sahabuddin Latif contributed to the research. concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

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