İZÜFBED İZÜ Fen Bilimleri Enstitüsü Dergisi
IZU Journal of Institute of Science and Technology

İZÜFBED 2025, 7(2), 62-88 DOI: https://doi.org/10.47769/izufbed.1673041
Araştırma Makalesi (Research Article)

İlkokul Dersliklerinde Günışığı Performansının Saydam Yüzey Oranı ve Cephe Yönelimine Göre Analizi: Necmettin Öztürk İlkokulu Örneği

Nur Sümeyye YALÇIN KOÇAK[a]

Erdem KÖYMEN[b]

Enes YAŞA[c]

Öz

Eğitim yapılarında doğal aydınlatma hem görsel konforun sağlanması hem de enerji verimliliğinin artırılması açısından kritik bir tasarım bileşeni olup, öğrencilerin öğrenme performansı üzerinde doğrudan etkili bir rol oynamaktadır. Bu çalışmada, İstanbul'un Ümraniye ilçesinde yer alan Necmettin Öztürk İlkokulu'nda bulunan iki farklı derslik üzerinden doğal aydınlatma performansı değerlendirilmiştir. Saydam yüzey oranı, pencere konumlandırması ve cephe yöneliminin günışığı performansı üzerindeki etkileri, iklim verilerine dayalı simülasyon yöntemiyle analiz edilmiştir. Rhino-Grasshopper ortamında Honeybee eklentisi ile gerçekleştirilen çalışmada, Mekansal Günışığı Özerkliği (sDA), Yıllık Güneşlenme Maruziyeti (ASE) ve Faydalı Gün Işığı Aydınlığı (UDI) metrikleri kullanılmıştır. Bulgular, mevcut saydam yüzey oranlarının günışığını sınıf içerisinde homojen ve yeterli düzeyde sağlamada yetersiz kaldığını göstermekte; önerilen açıklık düzenlemeleriyle ise Derslik 1/A' da önemli iyileşmeler sağlandığı görülmektedir. Çalışma, özellikle yapı çevresindeki yapılaşma yoğunluğu, cephe yönlenmesi ve iç yüzey özelliklerinin doğal aydınlatma performansını doğrudan etkilediğini ortaya koymakta; bu doğrultuda, özellikle yeni inşa edilecek eğitim yapılarında doğal aydınlatma analizlerinin erken tasarım aşamasında yapılmasının önemini vurgulamaktadır.

Anahtar Kelimeler: *Doğal aydınlatma, Günışığı performansı, Saydam yüzey oranı, Cephe yönelimi, Eğitim yapıları*

Makale Hakkında

Geliş Tarihi: 09.04.2025
Kabul Tarihi: 02.06.2025
Yayım Tarihi: 30.12.2025

Atıf için: Yalçın Koçak., N. S., Köymen, E., Yaşa, E. (2025). İlkokul Dersliklerinde Günışığı Performansının Saydam Yüzey Oranı ve Cephe Yönelimine Göre Analizi: Necmettin Öztürk İlkokulu Örneği. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 7(2), 62-88. https://doi.org/10.47769/izufbed.1673041

Etik Beyan

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur (Nur Sümeyye YALÇIN KOÇAK).

[a] **Sorumlu Yazar:** İstanbul Ticaret Üniversitesi, Mimarlık ve Tasarım Fakültesi, Mimarlık Bölümü, Türkiye. E-mail: nsykocak@ticaret.edu.tr ORCID https://orcid.org/0000-0002-5147-2599

[b] İstanbul Sabahattin Zaim Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, İç Mimarlık ve Çevre Tasarımı Bölümü, Türkiye. E-mail: erdemkoymen@yahoo.com ORCID: https://orcid.org/0000-0002-6924-421X

[c] İstanbul Teknik Üniversitesi, İç Mimarlık ve Çevre Tasarımı Bölümü, Türkiye. E-mail: enesyasa@yahoo.com ORCID: https://orcid.org/0000-0001-5705-5932

* Bu çalışmanın hazırlanma sürecinde, yapay zekâ tabanlı araçlar yalnızca dil ve üslup iyileştirme amacıyla kullanılmıştır. Çalışmanın tüm içeriği, yazar(lar) tarafından bilimsel araştırma yöntemleri ve akademik etik ilkelere uygun şekilde üretilmiştir.

Daylight Performance in Primary School Classrooms Based on Transparent Surface Ratio and Facade Orientation: A Case Study of Necmettin Öztürk Primary School

Nur Sümeyye YALÇIN KOÇAK[a]

Erdem KÖYMEN[b]

Enes YAŞA[c]

Abstract

In educational buildings, natural lighting is a critical design component in terms of both providing visual comfort and increasing energy efficiency, and it plays a direct role in students' learning performance. In this study, natural lighting performance was evaluated in two classrooms located in Necmettin Öztürk Primary School in the Ümraniye district of Istanbul. The effects of parameters such as transparent surface ratio, window positioning and façade orientation on daylight performance were analyzed using simulation based on climate data. The study, conducted in the Rhino–Grasshopper environment with the Honeybee plugin, employed the Spatial Daylight Autonomy (sDA), Annual Solar Exposure (ASE), and Useful Daylight Illuminance (UDI) metrics. The findings show that the existing transparent surface ratios are insufficient to ensure a homogeneous and adequate level of daylight within the classroom. However, significant improvements were achieved in Classroom 1/A with the proposed openness arrangements. The study reveals that the density of surrounding construction, façade orientation, and interior surface features directly affect natural lighting performance; in this regard, it emphasizes the importance of conducting natural lighting analyses during the early design stage, particularly for newly constructed educational buildings.

Keywords: *Natural lighting, Daylight performance, Transparent surface ratio, Facade orientation, Educational buildings*

About Article

Received Date: 09.04.2025
Accepted Date: 02.06.2025
Publication Date: 30.12.2025

To Cite: Yalçın Koçak., N. S., Köymen, E., Yaşa, E. (2025). Daylight Performance in Primary School Classrooms Based on Transparent Surface Ratio and Facade Orientation: A Case Study of Necmettin Öztürk Primary School. *Istanbul Sabahattin Zaim University Journal of Institute of Science and Technology,* 7(2), 62-88. https://doi.org/10.47769/izufbed. 1673041

Ethical Statement

It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited (Nur Sümeyye YALÇIN KOÇAK)

[a] **Corresponding Author:** İstanbul Ticaret University, Faculty of Architecture and Design, Architecture Department, Türkiye. E-mail: nsykocak@ticaret.edu.tr ORCID https://orcid.org/0000-0002-5147-2599

[b] İstanbul Sabahattin Zaim University, Faculty of Engineering and Natural Sciences, Department of Interior Architecture and Environmental Design, Türkiye. E-mail: erdemkoymen@yahoo.com ORCID: https://orcid.org/0000-0002-6924-421X

[c] İstanbul Technical University, Department of Interior Architecture, Türkiye. E-mail: enesyasa@yahoo.com ORCID: https://orcid.org/0000-0001-5705-5932

* During the preparation of this study, artificial intelligence-based tools were used solely for the purpose of improving language and style. All content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

1. INTRODUCTION

Lighting control and visual comfort are key aspects of physical environmental control. Classrooms are considered the central spaces of the educational process; therefore, it is of great importance that they have sufficient and homogeneous natural lighting. Artificial lighting is used when natural light is inadequate. In addition to creating comfortable and healthy environments, it is important to use energy and natural resources efficiently. However, ensuring visual comfort for users is critical to the quality and efficiency of the learning environment, extending beyond the lighting design itself. Therefore, lighting design should be carefully planned to balance energy efficiency and user comfort (Çelik & Ünver, 2019). Providing effective lighting in educational buildings is a complex process, as it must meet the needs of a multifaceted environment where students perform activities such as reading, writing, and viewing the board, while maintaining continuous student–teacher communication (Ashrafian & Moazzen, 2019). The inadequacy of natural lighting makes this process even more difficult and negatively affects user health. According to research by the Chinese Ministry of Education, the rate of myopia among university students was 84.72% in 2010, while it exceeded 90% in 2020. This shows that the quality of daylight in classrooms is critical for student comfort and visual health (Liu et al., 2022). Daylight not only supports visual perception but also contributes to eye development and helps reduce the risk of myopia in young individuals. Moreover, daylight plays a fundamental role in maintaining bone health by promoting vitamin D synthesis through the skin (Wirz-Justice et al., 2021). In this context, providing adequate natural lighting in educational buildings is essential for both academic success and long-term health.

Studies on daylight in educational settings have shown that natural lighting has a significant positive effect on students' academic performance. Students in classrooms illuminated by daylight progress 20% faster on math exams and 26% faster on reading exams compared to those in classrooms lit artificially (Heschong, 1999). However, while a 7% increase in test scores is observed in classrooms with the highest levels of daylight, this improvement ranges from 14% to 18% for students in classrooms with the largest window areas (Heschong et al., 2002). Climatic conditions and building design parameters directly affect natural lighting performance in the classroom. Window-to-wall ratio, window location, glass properties, and shading elements are the determining factors in daylight distribution (Alwetaishi, 2019; Alwetaishi & Benjeddou, 2021). Studies demonstrate the influence of façade orientation and transparent surface ratio on energy loads and visual comfort in natural lighting design (Ashrafian & Moazzen, 2019; Atthaillah et al., 2022).

Table 1

Literature Review on Natural Lighting in Educational Buildings

Ref.	Volume Dimensions	Examined Factor(s)	Purpose(s)
[1]	Rectangular volume classes	Window-Wall ratio, Window location, Floor, Wall reflection, Climate	DF
[5]	Comparison of 2 prototype schools	Window-Wall ratio, Orientation, Climate	DF
[6]	8,6m×7,2m×2,9m	Window-to-Wall ratio, Window configuration	Illuminance level, DF, Predicted percentage dissatisfaction (PPD), Predicted mean vote (PMV)
[7]	7m×8m×3,5m	Window height, Window-Wall ratio, Wall slope, Glass permeability	UDI250-750lx, sDA300/%50, ASE1000,250
[14]	8m×7,5m×3m	Floor-wall reflectance, window transmittance, window-wall ratio, distance between windows, sill height, window height, shading height, canopy width, shading reflectance value	UDI250-750lx, sDA300/%50, ASE1000,250
[15]	Rectangular volume classes	Opening to floor ratio, Window-Wall ratio	DF
[26]	8,4m×7,2m×3,8m	Window-to-Wall Ratio, Window configurations, Window sill height,	UDI, DA, Luminance distribution, Visual discomfort and glare
[34]	Primary school	Window area, Side lighting design strategies (Location of windows)	Illuminance level
[37]	9m×7m×3,3m	Light shelves, Environmental variables such as amount and quality of daylight, time, date and direction	Illuminance level

[43]	7.2m×7.2m×3.3m	Integrated lighting, Reflection factor	Illuminance level

As seen in Table 1, studies from different geographical regions show that shading elements and dynamic façade systems can improve natural-lighting performance, and that optimum window design supports visual comfort by preventing glare while increasing illuminance levels in classrooms (Ma'bdeh & Matar, 2020; Sabbagh et al., 2022). Studies conducted in educational buildings located in hot-climate regions show that high window-to-wall ratios can cause overheating due to direct solar radiation, whereas optimum window areas and shading strategies can balance energy consumption (Ekasiwi et al., 2018). Research indicates that interior-surface reflectivity contributes to a more balanced distribution of light within interior spaces (Aydın Yağmur & Şerefhanoğlu Sözen 2016). Studies conducted in Türkiye emphasize that constructing standard school projects based on generalized design principles, without considering climatic conditions, may negatively affect natural-lighting efficiency in certain regions (İyican & Turcan, 2018). Therefore, it is concluded that typical projects should be optimized by considering climatic differences (Abdelatia, 2010; Ashrafian & Moazzen, 2019). In light of these studies, the effectiveness of natural lighting in educational buildings can be increased by considering façade orientation, window dimensions, interior-surface reflectivity, and shading systems holistically. The literature shows that design approaches suitable for regional climatic conditions should be developed, and that energy efficiency can be enhanced by optimizing the use of natural light at the building scale (Alwetaishi, 2019; Ma'bdeh & Matar, 2020). In this study, the natural-lighting performance of two classrooms on the first floor of Necmettin Öztürk Primary School — a 24-classroom building located in Istanbul — was examined. The analysis employed the metrics of Spatial Daylight Autonomy (sDA), Annual Solar Exposure (ASE), and Useful Daylight Illuminance (UDI). Within the scope of the study, the effects of changes in existing window ratios, placement, and transparent surface areas on daylight performance were comparatively evaluated. Based on the findings, design recommendations were developed to optimize natural lighting in educational buildings commonly implemented in Türkiye. The analysis results revealed that especially the environmental structure density and the façade orientation of the building were determinant on the classroom illuminance levels.

1.1 Parameters Affecting Daylight Performance

In order for a space in a building to receive daylight, some factors need to be taken into account. These are also affected by architectural factors such as the area and location of transparent surfaces, prevention of light transmission (openness), color of interior surface materials (Ekasiwi et al. 2018), dimensions of the volume, interior surface reflection factors, and location of furniture. The parameters to be examined in this section are determined as the location of the structure, area and location of transparent surfaces, interior surface reflection factors, and dimensions of the classroom volume, and are detailed specifically for the study.

1.1.1 Location and Facade Orientation of the Structure

Since each structure will differ according to the geographical characteristics of the region where it is located, single-type projects are not efficient in terms of receiving daylight and cannot effectively benefit from natural lighting (Tavşan & Yanılmaz, 2019; Demir, 2012). In this context, the topographical condition and ground structure of the plots are of great importance. Especially in earthquake-prone regions such as Istanbul, the correct evaluation of the topography and ground conditions of the plots is a critical step to ensure the safety and durability of buildings. However, since the land is prepared by assuming that it is flat in typical projects, problems are encountered during the implementation phase. For example; In some places in Istanbul, ground water observed up to 4 m causes the addition of an additional basement floor to the structure, changes in original plans and increases costs (Köse & Barkul 2012). In addition, while placing the typical land, attention is not paid to the orientation, it is observed that it is placed randomly or facing the view or the main road. (İyican &Turcan 2018).

The south direction is considered an ideal direction for natural lighting as it receives more sunlight throughout the day. The north direction provides daylight without exposure to radiation. The west and east directions are more difficult to control and cause unwanted heat increases due to the horizontal movement of the sun during the day (Yüksek et al. 2015). However, these principles may vary depending on the building location, climate conditions and design goals. The unique needs and conditions of each project should be taken into account. Maximum use of daylight in buildings is a critical factor in minimizing energy consumption for lighting, heating and cooling (Djalilova & Şahin, 2018)

1.1.2. Area and Location of Transparent Surfaces

The opaque-transparent surface ratio is of great importance in the efficient use of natural lighting. Windows are the most important building component affecting this ratio and directly affect the level of illumination. Window location and size play a critical role in ensuring that the light entering the space is distributed homogeneously (Uc & Öztürk, 2022). In particular, windows should be directed correctly. This helps optimize lighting levels. In addition, care should be taken to ensure that windows are not behind students to avoid glare. In this case, students' eyes are prevented from getting tired, the silhouette effect is not created, and glare is minimized. The correct selection of window location and size contributes to students having a more comfortable and efficient learning experience (Çelik & Ünver, 2019; Ashrafian & Moazzen, 2019). A large window is expected to distribute daylight more homogeneously compared to a small window. In this context, a glazing ratio of 40% is recommended for the south, east and west facades and 55% for the north facade. Transparent surfaces bring both natural light and the outside view to the interior. It affects not only light but also environmental factors such as heat and sound insulation and energy efficiency (Ashrafian & Moazzen, 2019). In order to improve the energy performance of the building, the ratio and configuration of opaque transparent surfaces should be taken into account at the early design stage (Alwetaishi & Benjeddou 2021). Bernardo et al. (2017) concluded that better use of daylight could reduce energy consumption in school buildings by more than 10%, while Ashrafiana & Moazzen (2018) stated that a 50% transparency ratio would reduce the need for artificial lighting by at least 15% and provide more comfortable conditions. It is stated that the ratio of window area to classroom area in classrooms should be at least 25% according to the MEB Educational Buildings Minimum Design Standards Guide (2015) and that this ratio can be increased up to 50% depending on the characteristics of the climate zone in which it is located.

According to the MEB Educational Buildings Minimum Design Standards Guide (2015);

• The classroom should be designed so that daylight comes from the left side for the student, and furnishings and door openings should be arranged accordingly.

• Windows should start from the parapet at a minimum of 90 cm from the finished floor slab of the space they are located in, the window handle should be placed at a minimum of 140 cm from the finished floor slab, and safety measures should be taken with details to prevent falling on the opened wings.

• The wing opening should not exceed 80-85 cm on all opened wings and there should also be a double-axis use option. At least 2 windows should be made in transoms, the transom opening should be planned on the upper level and its height should not be wider than 70 cm.

• Primary school and secondary school classrooms should be formed with three openings arranged at 2.60 m intervals, and the classroom width should be 7.00 m.

• Glass with a high light transmittance factor should be used in the windows. Dark glass reduces the amount of daylight entering the interior and causes users to be misinformed about the external environment features and time. (Ünver) According to the publication of the Ministry of National Education, Construction and Real Estate Department (2015) "Educational Institutions Construction Works Site Lists and

Explanations", the light transmission coefficient of the specified window glass should be 0.60.

1.1.3 Reflective Properties of Interior Surfaces

Light reflectance factors of interior surfaces are an important parameter that directly affects the visual comfort of spaces. Especially in spaces with long-term use such as educational buildings, the reflective properties of interior surfaces are of great importance in terms of brightness level, luminance ratios and energy efficiency (Aydın Yağmur & Şerefhanoğlu Sözen 2016).

The lower and upper limits recommended for interior surface reflectance factors for ceiling, wall and floor in the TS EN 12464-1 Standard are 0.70, 0.50, 0.20 and 0.90, 0.80, 0.60. (TS EN 12464-1:2021, Ünver). These values indicate that the ceiling should have high reflectance, the walls reflect light at a moderate level and the floor may have a low reflectance factor. Thus, the ceiling reflects the light coming into the space in the most efficient way and provides a homogeneous distribution, while the walls contribute to the spread of light and the flooring prevents unnecessary reflections and increases visual comfort. The use of light colors on the ceiling and walls ensures a more homogeneous distribution of light, while surfaces with low reflectivity should be used to create better contrast and perception, especially in certain areas such as the work plane.

The brightness and opacity levels of interior surfaces in educational buildings directly affect the lighting performance of the space, the visual comfort of the users and energy consumption. Especially in educational spaces such as classrooms, whether the surfaces are glossy or matte is one of the basic factors that determine how the light is distributed in the space and the visual perception of the users. In the study conducted by Aydın Yağmur and Şerefhanoğlu Sözen (2016), it was determined that glossy surfaces create unwanted reflections and cause glare. While students evaluate glossy white surfaces as the most disturbing surfaces, it was determined that matte and light gray tones increase visual comfort. Similarly, it was observed that black and dark surfaces absorb too much light and make visual perception difficult.

Light reflectance factors of interior surfaces play a critical role not only in terms of visual comfort but also in terms of energy efficiency. According to research by Ünver (2015), light-colored and highly reflective surfaces contribute to energy saving by reducing the need for artificial lighting.

1.1.4 Dimensions of the Classroom Volume

In order to evaluate and optimize the natural lighting performance in buildings, it is necessary to relate the spatial depth to the window size and surface reflectance properties. In this context, British Standard BS 8206-2:1992 provides the following equation, which determines the maximum depth of the room to ensure effective distribution of daylight in interior spaces illuminated by a single lateral window[1]:

$$\frac{L}{W} + \frac{L}{Hw} < \frac{2}{1 - Rb} \qquad 1$$

Here, L represents the room depth, W represents the width, Hw represents the height of the upper edge of the window, and Rb represents the average reflection factor of the surfaces. The equation shows that the room depth should be kept below a certain limit in order for daylight to reach the depths of the space effectively. If the space is too deep, the need for artificial lighting increases due to the inability of daylight to reach the back areas sufficiently.

In their study, Köse and Kazanasmaz (2019) stated that as the room depth increases, the window-wall ratio should also be optimized to ensure a homogeneous distribution of natural lighting.

According to the MEB Educational Buildings Minimum Design Standards Guide (2015), classrooms in educational buildings should be planned according to a capacity of 30 students. In classrooms, the storage areas that open directly to the classroom for the storage of course materials should be between 3 and 5 m^2 in size. In order to ensure that the classroom has sufficient movement space and an ergonomic learning environment in accordance with the number of students, the gross area per person, excluding the storage area, must be at least 1.60 m^2 in primary schools and at least 1.85 m^2 in secondary and high schools

1.2 Daylight Performance Metrics

Climate-based daylight metrics are used as an important analysis tool to evaluate daylight performance in a space. Metrics such as sDA, ASE and UDI help determine how daylight is distributed in a space, what the level of excessive sunlight exposure is and how it affects user comfort.

Table 2

Characteristics of sDA, ASE and UDI metrics in evaluating daylight performance

Metric	sDA	ASE	UDI
Analysis Period	10 hours per day (08:00 - 18:00)	-	-
Brightness Threshold	300 lux	1000 lux	100-2000 lux
Temporal Threshold	1825 hours per year	250 hours per year	1825 hours per year
Target	55% < sDA < 75%	ASE < 10%	UDI > %50

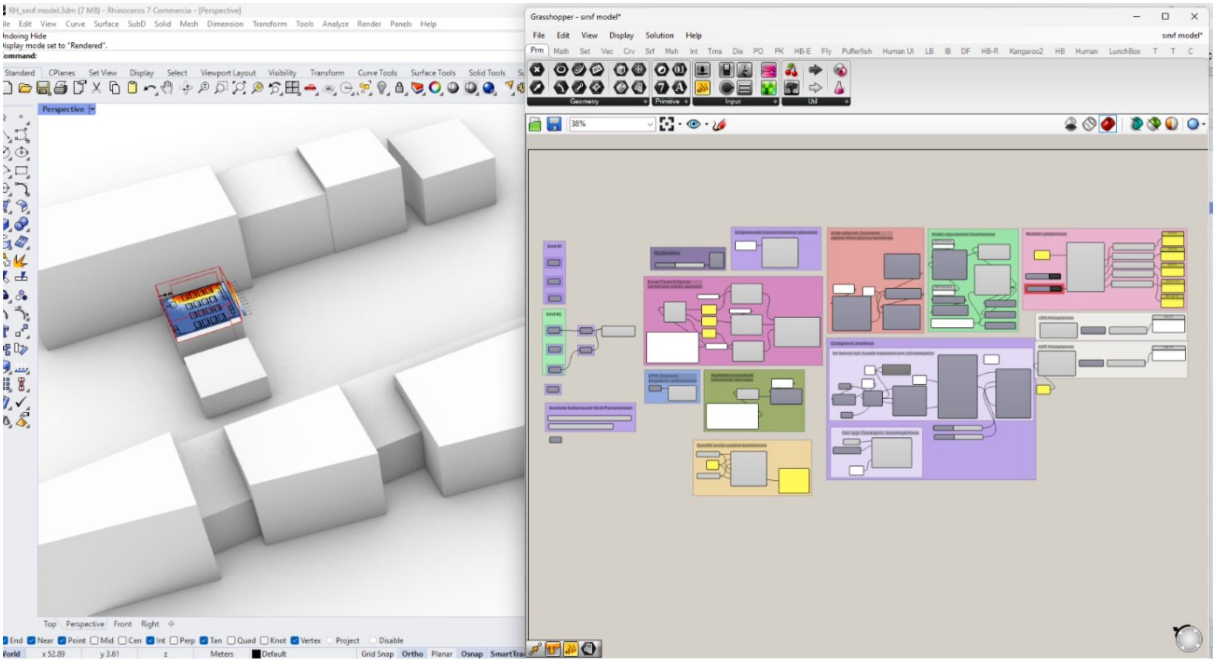
Table 3 summarizes the analysis criteria of sDA, ASE and UDI metrics used to evaluate the natural lighting performance of a space. According to the table, an area should receive 300 lux or more daylight for at least 50% of the annual working hours (sDA300/%50 ≥ 55%) and no more than 10% of the area should be exposed to direct sunlight exceeding 1000 lux for more than 250 hours per year (ASE1000,250 ≤ 10%) (Mahdavinejad et al. 2024). In addition, the UDI metric, which evaluates the useful daylight illuminance, states that the percentage of illuminance remaining in the range of 100-2000 lux should be above 50% (Nabil & Mardaljevic, 2005).

2. MATERIAL AND METHOD

Within the scope of this study, the natural lighting performance of two classrooms (1/A and 1/D) located on the first floor of Necmettin Öztürk Primary School in Ümraniye district of Istanbul was analyzed by simulation method. The research was carried out in two stages, first evaluating the current situation and then evaluating the proposed design solutions. In order to examine the effects of existing and proposed transparent surfaces on daylight performance in the analyzed spaces, Grasshopper plugin and Honeybee tools working in Rhino software environment were used (Figure 1). Honeybee tools were preferred to perform climate-based daylight simulations.

Figure 1

Daylight simulation model (Rhinoceros3D/Grasshopper3D)



The climate data used in the simulations were obtained from the EPW (Energy Plus Weather) file of Istanbul. In the analyses, the working surface inside the classroom was created at a height of 0.85 m from the ground and 0.5 m from the classroom boundaries. Sensor grids were created on the working plane for each classroom and annual daylight performance was analyzed. Considering the currently used interior surface materials, the reflection factors of the ceiling, wall and floor surfaces were defined in the simulations in accordance with real conditions. According to the current paint and coating materials observed in the classrooms; ceiling surfaces were covered with white matte paint and included in the simulation with a reflection coefficient of 0.80, walls were in light pastel tones and included in the simulation with a reflection coefficient of 0.60, and floors were covered with dark ceramic coating and included in the simulation with a reflection coefficient of 0.10. These values were determined in accordance with the literature in order to model the way light spreads in the interior space as close to reality as possible. The basic evaluation criteria of the study were Spatial Daylight Autonomy (sDA), Annual Solar Exposure (ASE) and Useful Daylight Illuminance (UDI) metrics. These metrics were used to evaluate the visual comfort of users and the amount of daylight in indoor spaces. In the light of the data obtained as a result of the simulation, the current situation and the proposed situation with extended transparent surfaces were compared and evaluated. Within the scope of this study, some parameters affecting the natural lighting performance were considered as fixed and some as variable. The parameters kept constant include; interior surface material reflectance factors, space geometry, classroom furniture arrangement and sensor grid height. These values were fixed based on current observations in order to model the physical conditions closest to reality. Only the transparent surface area and location were considered as variable parameters. With this approach, the effect of the change in the ratio of transparent surfaces on daylight performance could be directly examined.

2.1 Case Study

In Türkiye, 19 million students receive education at preschool, primary school, middle school and secondary school levels. The statistics of the Ministry of National Education show that 19,904,679 students were educated in 751,569 classes in Türkiye in the 2022-2023 academic year, and 1,154,383 teachers were providing education (Ministry of National Education, 2023). When other service personnel are added to this number, the number of people spending time in schools increases much more. However, when additional courses given to students on weekends are also considered, students spend almost all their time in school areas (Djalilova & Şahin, 2020; Gülşeker 2018).

For this reason, it is necessary to improve the physical conditions of the spaces or pay attention to this in the early design stage so that developing children can become healthy individuals, correctly comprehend the education given, and not experience concentration problems.

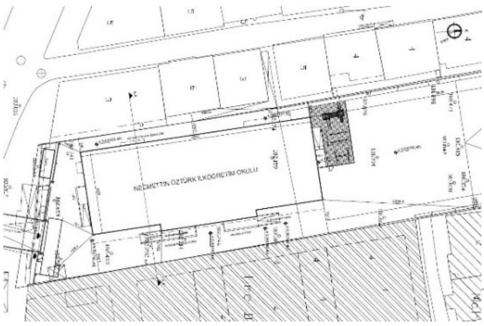
Although Necmettin Öztürk Primary School was not constructed within the scope of a typical project, it was evaluated as a case study in this study because it has the basic design criteria affecting daylight performance in terms of façade orientation, openness ratio and environmental conditions. It was observed that factors such as dense construction around the school, façade orientation and opaque-transparent surface ratio limited natural light intake in certain classrooms; the effect of this situation on daylight performance was analyzed with simulation-based methods. Within the scope of the study, Class 1/A and Class 1/D located on the 1st floor were evaluated comparatively due to their different orientations. In these classrooms, daylight performance was simulated and the change in light levels over time and spatial distribution were examined with sDA, ASE and UDI metrics. The obtained data were evaluated in line with natural lighting standards and suggestions were developed to ensure optimum lighting conditions in educational spaces.

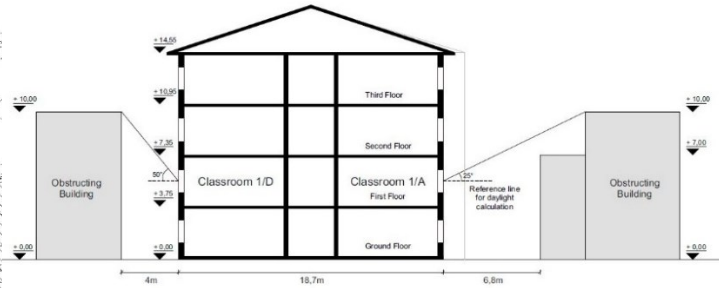
2.2 Definition and Characteristics of the Research Area

Necmettin Öztürk Primary School was built as Ground + 3 floors in Istanbul-Ümraniye Yamanevler Neighborhood and has 5126.66 m² closed education area and 1974 m² garden area. The school building was opened on September 22, 2023 and started its education-training activities. It provides education with the normal education method and the lessons are held between 08.50 - 14.30. Students receive education during this time period without any distinction between morning and afternoon. The site plan of the school are presented in Figure 2.

Figure 2

Site plan of Necmettin Öztürk Primary School Figure 3. Impact of surrounding buildings on daylight access.





Necmettin Öztürk Primary School is an educational structure with 24 classrooms and includes administrative units, special education classes, teacher and guidance rooms, children's library, conference and sports halls, dining hall, canteen and various workshops. It is also equipped with supporting spaces such as technical units, archive, kitchen, changing rooms and wet areas. Figure 3 shows the density of buildings and location of buildings around Necmettin Öztürk Primary School. The school is located in a region with a contiguous construction plan, with a narrow distance from the surrounding buildings (Figure 3,4). The classrooms are positioned on the east and west facades, and the buildings in the immediate vicinity are in these directions. Classroom 1/A on the east facade is bordered by a 10 m high building at a distance of approximately 6.8 m, while classroom 1/D on the west facade is surrounded by a 10 m high building at a distance of 4 m. This creates a sky view of approximately 25° on the east facade and 50° on the west facade, limiting daylight access (Figure 3).

Figure 3.

Exterior and immediate surrounding views of Necmettin Öztürk Primary School

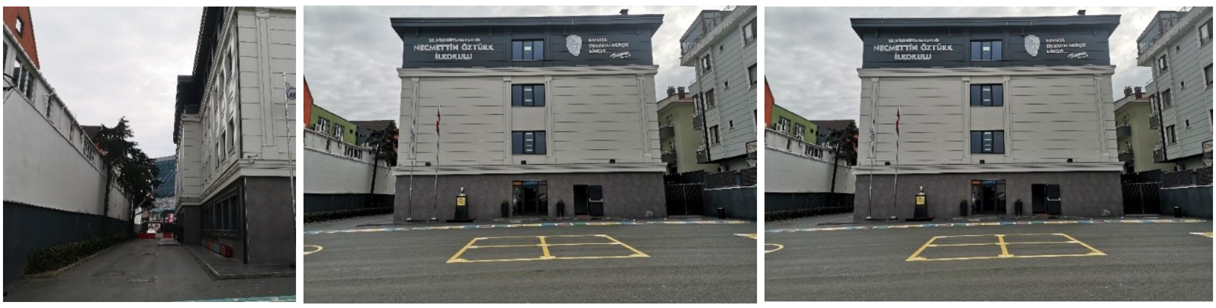
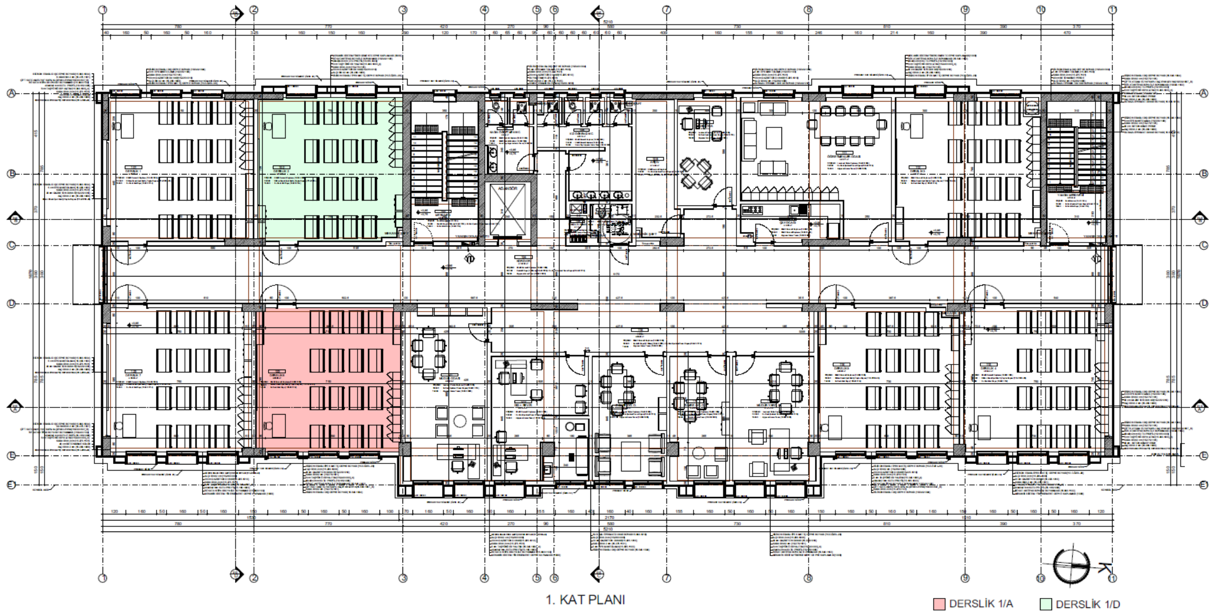


Figure 4 shows the first floor plan of Necmettin Öztürk Primary School. The plan includes classrooms, administrative units, teacher's room, guidance service and common areas. Classroom 1/A is marked in red, and Classroom 1/D is marked in green.

Figure 4

Necmettin Öztürk Primary School 1st floor plan and analyzed classrooms

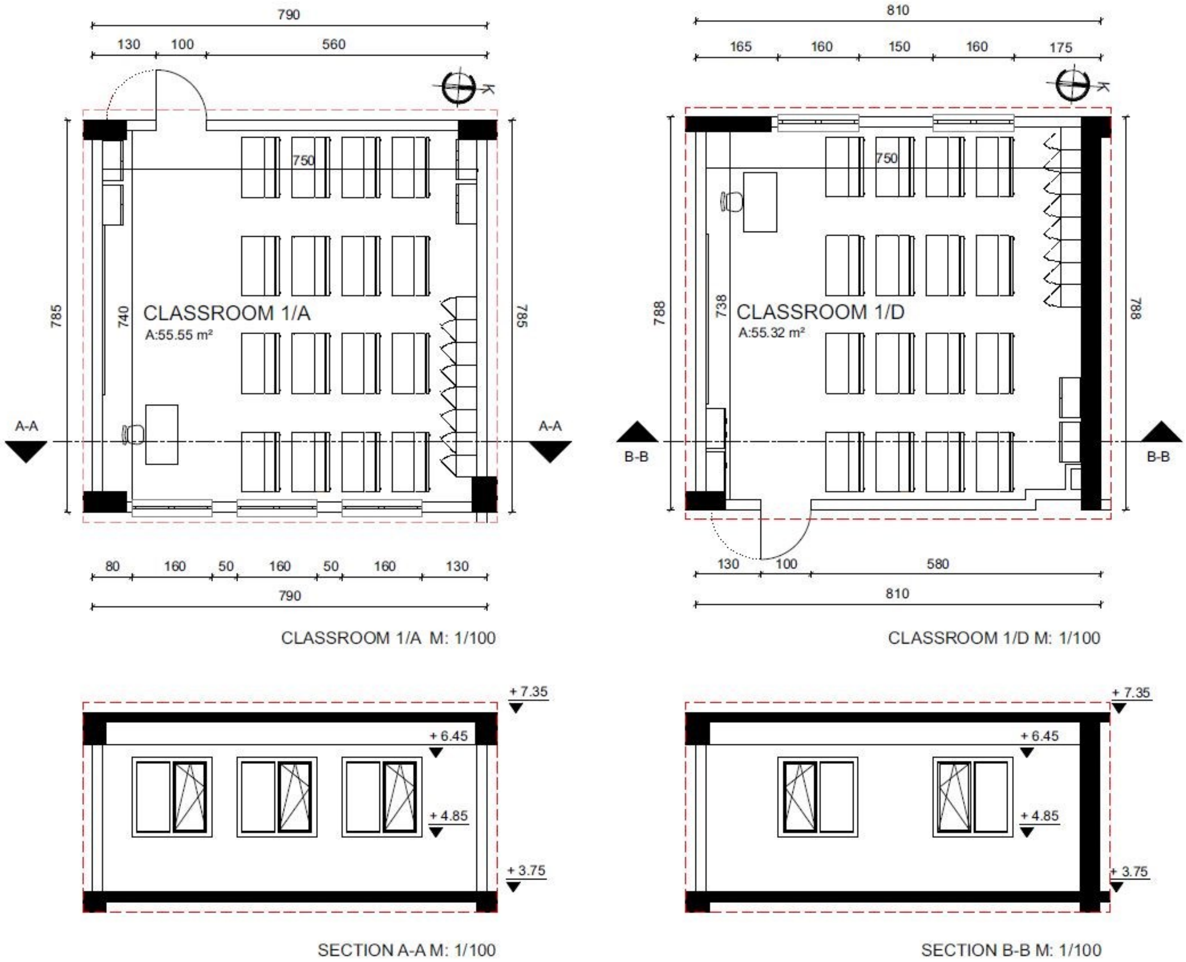


Classroom 1/A is located on the east side of the school building and its interior dimensions are approximately 7.5 m wide and 7.4 m deep; there are three windows in this classroom with dimensions of 1.6 m x 1.6 m and the opaque-to-transparent surface ratio is 27%.

Classroom 1/D is located on the west side of the school building and its interior dimensions are approximately 7.5 m wide and 7.35 m deep. There are two windows in this classroom with dimensions of 1.6 m x 1.6 m and the opaque-to-transparent surface ratio is 19%. In Figure 5, the plan and section drawings of both classrooms are detailed and the window locations and openings are clearly shown.

Figure 5

Current plans and sections of Necmettin Öztürk Primary School Classroom 1/A and Classroom 1/D



The classrooms have whiteboards, student desks, teacher's desks, cabinets and wall panels. The interior layout is designed so that students can easily see the board and support interaction within the classroom. Although windows provide natural light, there is variability in lighting levels due to the density of the surrounding buildings (Figure 6).

Figure 6.

Classroom 1/D (left) and Classroom 1/A(right)

Table 3 presents the volume information, material properties and window information of Classroom 1/A and Classroom 1/D analyzed within the scope of the study in a comparative manner.

Table 3

Features of Necmettin Öztürk Primary School classrooms

	Classroom 1/A		Classroom 1/D	
	Parameter	**Value**	**Parameter**	**Value**
Room Dimensions	Width Height Depth	7.5 m 3.4 m 7.4 m	Width Height Depth	7.5 m 3.4 m 7.38 m
Class Material Properties	Ceiling Reflection Wall Reflection Floor Reflection Window Transmission	0.8 0.6 0.1 0.6	Ceiling Reflection Wall Reflection Floor Reflection Window Transmission	0.8 0.6 0.1 0.6
Window Properties	Width Height Number of Windows Parapet Height Window Direction	1.6 m 1.6 m 3 1.1 m East	Width Height Number of Windows Parapet Height Window Direction	1.6 m 1.6 m 2 1.1 m West

3. Results And Discussion

In this section, the findings of the daylight performance analyses conducted in two selected classrooms within the scope of the study are presented and evaluations are made based on the simulation results. In the analyses, sDA, which measures the access of spaces to natural light throughout the year, ASE, which indicates excessive light exposure, and UDI, which determines the useful illumination range, were used. Both the data of the current window arrangement and the proposed scenarios with increased transparent surface ratios were comparatively examined for both classrooms. In addition, the annual sky illumination profile obtained from Istanbul's EPW climate file is presented graphically. This graph shows the outdoor illumination levels corresponding to hourly time periods throughout the year. The graph serves as a reference in terms of correlating the analyses with local climate conditions.

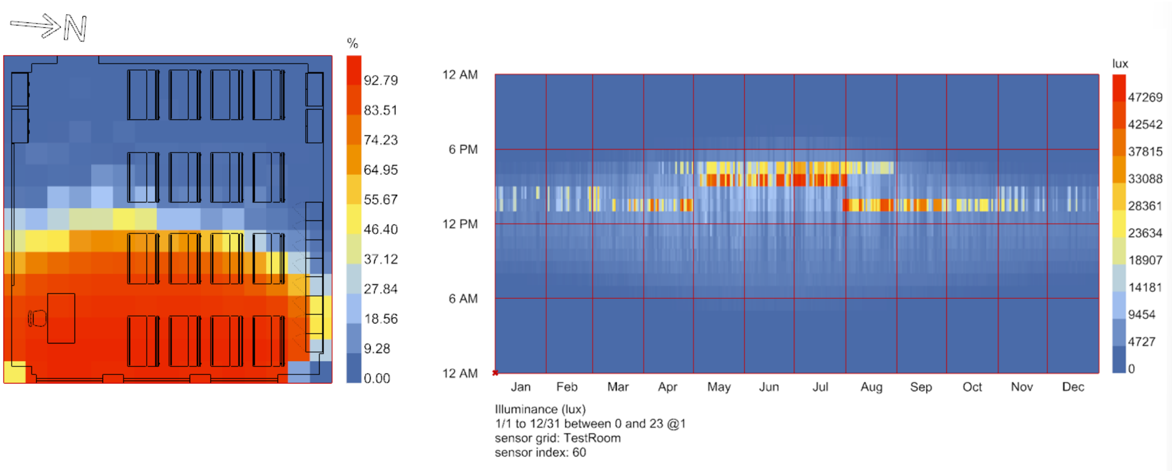
3.1. Current Situation Analysis of Classrooms

In this section, the natural lighting performance of Classrooms 1/A and 1/D was evaluated by taking into account the existing window ratio, façade orientation and environmental construction conditions. The daylight simulation conducted for the current situation of Classroom 1/A reveals that natural lighting is insufficient and unbalanced in the classroom (Figure 7).

The analysis results show that daylight is mainly effective in the areas close to the window; while the remaining lighting levels are insufficient in the majority of the classroom. This situation is also supported by numerical data: The sDA value was 39.55%, below the recommended minimum value of 55%, indicating that natural light cannot be provided for sufficient periods in the majority of the classroom. The ASE value was calculated as 12.89%, indicating that there is a risk of glare due to light exposure in the interior space. The UDI value was measured as 51.70%, indicating that more than half of the interior space remains at low lighting levels. This indicates the inadequacy of natural lighting and the need for artificial light.

Figure 7

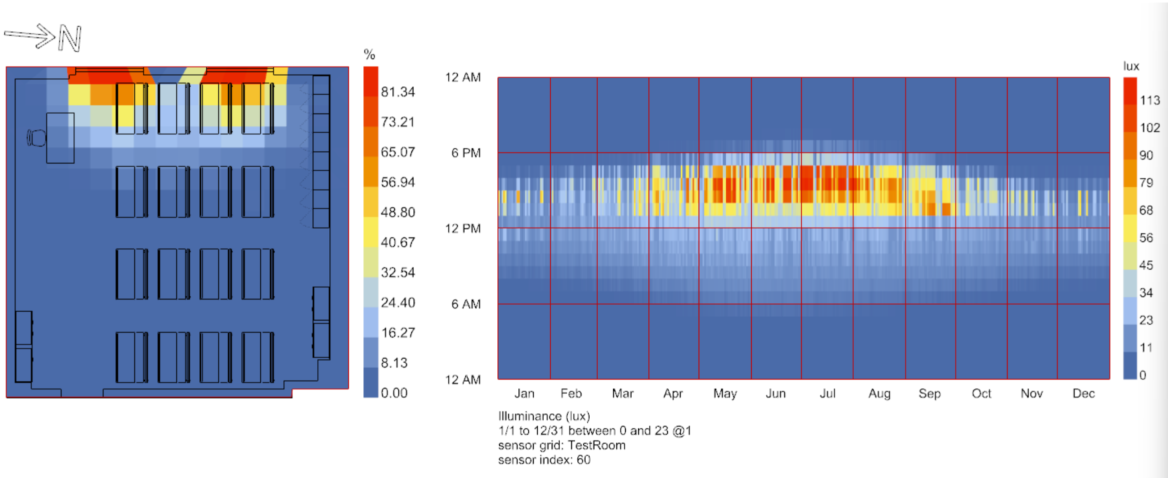
Current situation analysis of Classroom 1/A



The current situation of Classroom 1/D is shown in Figure 8. The simulation data show that the classroom receives a certain amount of daylight, especially in areas close to the windows, but low illumination levels prevail throughout the classroom. According to the data obtained, the sDA value was measured as 3.64%, which is well below the accepted threshold of 55%. The ASE value is 0%, which indicates that the classroom is not exposed to excessive sunlight. However, the UDI value is only at 15.90%.

Figure 8

Current situation analysis of Classroom 1/D



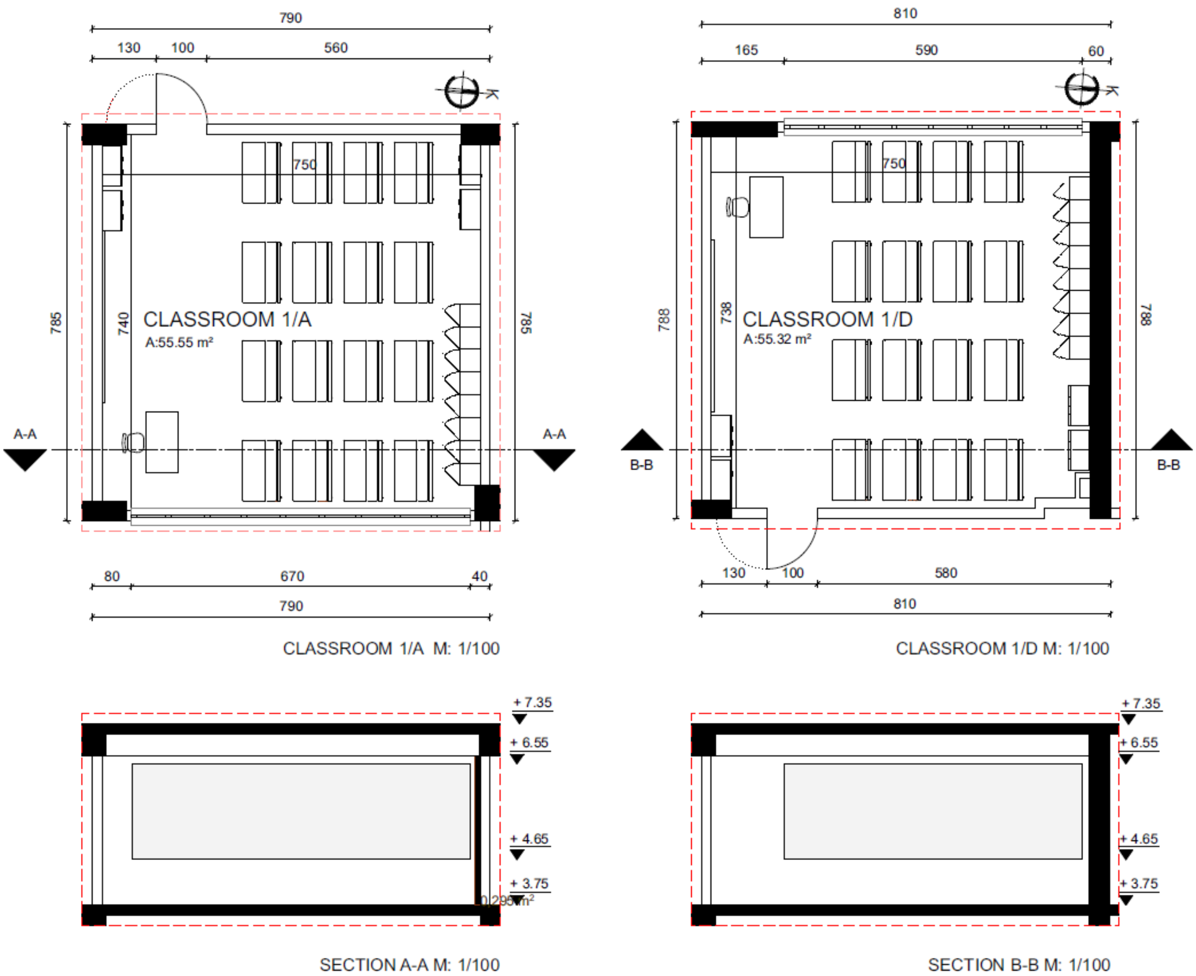
These findings show that the current window size and environmental conditions are insufficient to provide sufficient and balanced natural lighting in the classroom.

3.2. Alternative Transparent Surface Analysis of Classrooms

Considering the minimum design criteria determined by the Ministry of National Education (MEB) for educational buildings, all surfaces other than the load-bearing elements were designed as transparent surfaces. In this approach, transparent surfaces were maximized along the facade, aiming to distribute daylight more homogeneously within the space. It was emphasized in the MEB Minimum Design Guide that the window parapet height should be at most 90 cm; in this study, this criterion was taken into consideration and the parapet height was applied as 90 cm (Figure 9). This application is shown in detail in the plan and section drawings. However, the effectiveness of this proposed solution should be considered not only with the dimensions of the openings, but also with the orientation of the structure and environmental obstacles.

Figure 9

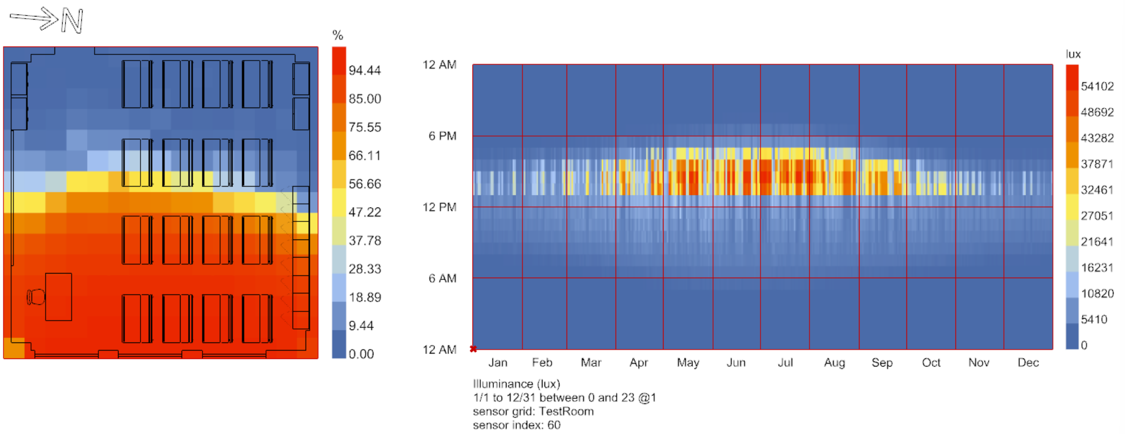
Alternative plans and sections of Classroom 1/A and Classroom 1/D



The daylight simulation results of the alternative case where the transparent surface area is increased for Classroom 1/A are presented in Figure 10. As a result of this intervention with larger transparent surfaces compared to the current situation, it was observed that natural lighting in the classroom was significantly improved. According to the simulation data, the sDA value reached 53.77%, very close to the ideal threshold value of 55%. This situation indicates a significant improvement in terms of access to daylight. The ASE value is 25.33%, and there is a risk of glare due to excessive lighting in the classroom. The UDI value was calculated as 56.81%. These results show that increasing the window ratios significantly improves daylight performance, provides natural lighting in a larger part of the classroom, and this situation can positively affect the visual comfort of the students

Figure 10

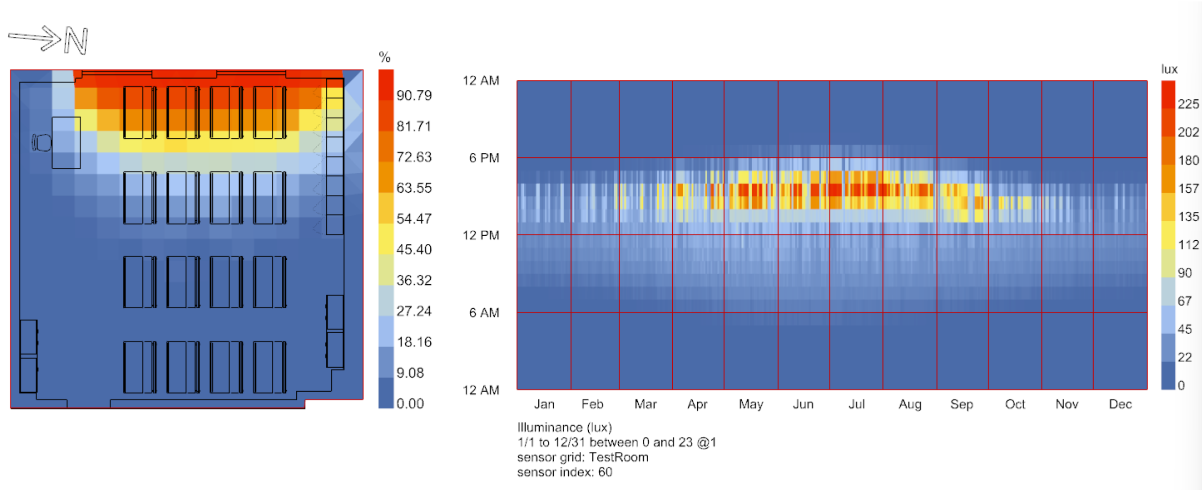
Alternative case analysis of Classroom 1/A



The analysis presented in Figure 11 shows the daylight performance of an alternative proposal scenario for Classroom 1/D. In this proposal, despite the increase in the window surface area, the performance values obtained did not reach the expected level. According to the simulation data, the sDA value is at a very low level of 11.58%, which indicates that sufficient natural light cannot be provided in a significant part of the classroom. The UDI value was determined as 30.66%, the ASE value as 0, and it was determined that there was no excessive light exposure. However, the fact that the sDA value remained at a very low rate of 11% indicates that the majority of the interior space does not receive sufficient natural light throughout the year. This situation reveals that the daylight performance in the classroom is extremely poor and that the need for artificial lighting will be high.

Figure 11

Alternative case analysis of Classroom 1/D



This study shows that the correct design of window ratios in school buildings is a critical factor for increasing visual comfort of students. The analyses clearly show that natural lighting performance can directly affect the quality of education in classroom environments.

3.3. Comparative Assessment

Daylight performance data for the current and proposed cases of Classroom 1/A and 1/D are presented comparatively.

Table 4

Comparative evaluation of classes

Metric	1/A Current Situation	1/A Alternative	1/D Current Situation	1/D Alternative
sDA (%)	39.55	53.77	3.31	11.58
ASE (%)	12.89	25.33	0	0
UDI (%)	51.70	56.81	15.90	30.69

As seen in Table 4, increasing the window ratios in both classrooms provided a significant increase in sDA and UDI values, while ASE values remained low in all scenarios. This situation reveals the positive effect of the suggested scenarios on increasing visual comfort. However, the expected improvement was not achieved in some suggested cases; this showed that not only the size of the opening but also the environmental conditions are determinants of daylight performance.

4. CONCLUSION

This study was conducted on two classrooms (1/A and 1/D) in Necmettin Öztürk Primary School located in Istanbul for the evaluation of natural lighting performance in educational buildings. Both the current situation and the suggested scenarios were tested in a simulation environment for both classrooms; the effects of changes in transparent surface ratios on the daylight metrics sDA, ASE and UDI were analyzed. The findings revealed that the existing window openings were insufficient to distribute daylight homogeneously and sufficiently within the classroom. In particular, the dense construction around the building, façade orientation and limited use of transparent surfaces have caused low illuminance levels and unbalanced light distribution in the interior.

Improvements were observed in sDA and UDI values with the increase in transparent surface ratios. While ASE values remained low in Classroom 1/D and did not indicate excessive light exposure, they increased in Classroom 1/A. Despite the increased transparent surface ratio in Classroom 1/D, there was no significant improvement in daylight performance due to the building's orientation and the shading effects of the surrounding structures. These results clearly show that window design should be informed not only by surface ratios but also by context-sensitive analysis.

Classroom 1/A is located on the east façade, while Classroom 1/D is located on the west façade, and façade orientation has proven to be a direct determinant of daylight performance. In the alternative scenario, the sDA value in the east-facing Classroom 1/A reached 53.77%, whereas it remained as low as 11.58% in the west-facing Classroom 1/D. This difference is attributable not only to orientation but also to the vertical sky angles constrained by surrounding buildings. On the east façade, a relatively open sky view angle of approximately 25° allows for more daylight access, whereas the angle narrows to around 50° on the west façade, further limiting sky exposure. This indicates that the east-facing classroom—less obstructed during morning hours—achieves better daylight performance compared to the west-facing one. Therefore, both façade orientation and the density of surrounding structures are critical determinants of daylight performance.

Accordingly, the ratio and placement of transparent surfaces should be determined based on the unique environmental, orientational, and climatic conditions of each project. The orientation of classroom façades should be designed to maintain daylight continuity throughout the day, and window openings should be positioned to ensure even light distribution, independent of structural constraints. While the minimum design criteria provided by the Ministry of National Education offer a general guideline, simulation-supported assessments are essential where these criteria may fall short in ensuring adequate performance. Furthermore, not only the entry of daylight but also its internal distribution should be considered, incorporating factors such as interior surface reflectance, color palette, and furniture arrangement into the design process.

In conclusion, this study demonstrates that natural lighting design in educational buildings should adopt a context-aware and performance-driven approach rather than relying on standard solutions. Especially in new school projects, conducting daylight analysis during the early design phase should be regarded as a fundamental strategy for enhancing both student comfort and energy efficiency.

Etik

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur. Bu araştırma ile ilgili etik sorularınız için lütfen izufbed@izu.edu.tr adresine başvurun.

Katkı Oranı Beyanı

Bu çalışmada yazarlar eşit katkıda bulunmuşlardır.

Çatışma Beyanı

Yazarlar, bu makalenin araştırılması, yazılması veya yayınlanmasıyla ilgili herhangi bir çıkar çatışması olmadığını beyan ederler.

Ethical Considerations

It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited. For ethical inquiries regarding this research, please contact: izufbed@izu.edu.tr

Author Contributions

All authors made equal contributions to the research and the preparation of this manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare related to the research, writing, or publication of this manuscript.

KAYNAKÇA

Abdelatia, B., Marenne, C., & Semidor, C. (2010). Daylighting strategy for sustainable schools: case study of prototype classrooms in Libya. *Journal of Sustainable Development*, *3*(3), 60.

Acosta, I., Campano, M. Á., & Molina, J. F. (2016). Window design in architecture: Analysis of energy savings for lighting and visual comfort in residential spaces. Applied energy, 168, 493-506.

Al-Khatatbeh, B. J., & Ma'bdeh, S. N. (2017). Improving visual comfort and energy efficiency in existing classrooms using passive daylighting techniques. *Energy Procedia*, *136*, 102-108.

Alwetaishi, M. (2019). Impact of glazing to wall ratio in various climatic regions: A case study. *Journal of King Saud University-Engineering Sciences*, *31*(1), 6-18.

Alwetaishi, M., & Benjeddou, O. (2021). Impact of window to wall ratio on energy loads in hot regions: A study of building energy performance. *Energies*, *14*(4), 1080.

Ashrafian, T., & Moazzen, N. (2019). The impact of glazing ratio and window configuration on occupants' comfort and energy demand: The case study of a school building in Eskisehir, Turkey. *Sustainable Cities and Society*, *47*, 101483.

Atthaillah, A., Mangkuto, R. A., Koerniawan, M. D., Hensen, J. L., & Yuliarto, B. (2022). Optimization of daylighting design using self-shading mechanism in tropical school classrooms with bilateral openings. *Journal of Daylighting*, *9*(2), 117-136.

Bayram, İ., Kale, Ö. A., & Baradan, S. (2020). Eğitim binalarının aydınlatma performansı açısından değerlendirilmesi. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, *11*(2), 783-798.

Bernardo, H., Antunes, C. H., Gaspar, A., Pereira, L. D., & da Silva, M. G. *An approach for energy performance and indoor climate assessment in a Portuguese school building, Sustain. Cities Soc. 30 (2017) 184–194*.

British Standards Institution. BS 8206-2:1992. Code of Practice for daylighting. London: BSI, 1992.

Çelik, K., & Ünver, F. R. (2019). Eğitim yapılarında sürdürülebilir aydınlatma tasarımı yaklaşımı. *Çukurova Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi*, *34*(3), 49-64.

Dascalaki, E. G., & Sermpetzoglou, V. G. (2011). Energy performance and indoor environmental quality in Hellenic schools. *Energy and Buildings*, *43*(2-3), 718-727.

Demir, A. (2012). *Yeşil okul: çevre, sağlık ve eğitime etkileri* (Master's thesis, Inonu University (Turkey)).

Effendy, E. J., Hakim, F. N., Mangkuto, R. A., Koerniawan, M. D., & Ramadhani, D. (2023, April). Daylight optimization in a hypothetical classroom using single-objective optimization methods: Case study in Lhokseumawe, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1157, No. 1, p. 012002). IOP Publishing.

Ekasiwi, S. N. N., Antaryama, I. G. N., Krisdianto, J., & Ulum, M. S. (2018, March). Correlation of classroom typologies to lighting energy performance of academic building in warm-humid climate (case study: ITS Campus Sukolilo Surabaya). In *IOP Conference Series: Earth and Environmental Science* (Vol. 126, No. 1, p. 012049). IOP Publishing.

Erlalelitepe, İ., Aral, D., & Kazanasmaz, T. (2011). Eğitim yapılarının doğal aydınlatma performansı açısından incelenmesi. *Megaron, Yıldız Teknik Üniversitesi Mimarlık Dergisi*, *6*, 39-51.

Ershov, S., Sokolov, V., Galaktionov, V., & Voloboy, A. (2023). Virtual Light Sensing Technology for Fast Calculation of Daylight Autonomy Metrics. *Sensors*, *23*(4), 2255.

Heschong, L. (1999). Daylighting in Schools: An Investigation into the Relationship between Daylighting and Human Performance. Detailed Report.

Heschong, L., Wright, R. L., & Okura, S. (2002). Daylighting impacts on human performance in school. *Journal of the Illuminating Engineering Society*, *31*(2), 101-114.

İyican, B., & Turcan, Y. (2018, Eylül 6–7). *Eğitim yapılarında uygulanan "tip proje" kullanımında ortaya çıkan sorunlar: Pasif iklimlendirme* (ss. 101–114). III. International Rating Academy Congress on Applied Sciences, Lviv, Ukrayna.

Kazanasmaz, T., Grobe, L. O., Bauer, C., Krehel, M., & Wittkopf, S. (2016). Three approaches to optimize optical properties and size of a South-facing window for spatial Daylight Autonomy. *Building and Environment*, *102*, 243-256.

KÖSE, Ç., & BARKUL, Ö. (2012). İlköğretim Yapılarında Tip Proje Uygulama Sorunları Üzerine Bir İnceleme. *Megaron*, *7*(2). Yaraş, Z., Turan, M. (2021). Sınıf yönetimi engeli olarak istenmeyen davranışlar: kalitatif bir değerlendirme. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi,* 58, 573-600.

Köse, F. B., & Kazanasmaz, Z. T. (2019). *Prizmatik panellerin pencerelerde kullanımı ile doğal aydınlatma performansının değerlendirilmesi*. X. Ulusal Aydınlatma Sempozyumu, Türkiye.

Kumar, R. V., & Kumar, S. (2020). Spatial Day light autonomy and energy analysis of a residential building for different climatic conditions and window-to-wall ratios. In *E3S Web of Conferences* (Vol. 184, p. 01117). EDP Sciences.

Liu, G., Qu, G., Ren, L., Zhang, Y., Zang, X., & Dang, R. (2022). The influence mechanism of daylight visual evaluation in college classrooms under visual field physiological characteristics of student group: Case study. *Building and Environment*, *209*, 108655.

Ma'bdeh, S., & Matar, H. (2020). Designing a dynamic fenestration to improve visual performance in educational spaces using daylight. *Periodicals of Engineering and Natural Sciences*, *8*(3), 1898-1910.

Mahdavinejad, M., Bazazzadeh, H., Mehrvarz, F., Berardi, U., Nasr, T., Pourbagher, S., & Hoseinzadeh, S. *The impact of facade geometry on visual comfort and energy consumption in an office building in different climates. Energy Reports 11 (2024) 1–17.*

Milli Eğitim Bakanlığı İnşaat ve Emlak Dairesi Başkanlığı. (2013). *Eğitim yapıları asgari tasarım standartları kılavuzu*. Ankara, Türkiye.

Milli Eğitim Bakanlığı. (2023). *Ulusal eğitim istatistikleri – Resmi eğitim – 2022/2023*. Ankara, Türkiye: Milli Eğitim Strateji Geliştirme Başkanlığı.

Milli Eğitim Bakanlığı İnşaat ve Emlak Dairesi Başkanlığı. (2015). *İnşaat teknik şartname mahal listesi*. Ankara, Türkiye.

Mostafavi, F., Tahsildoost, M., Zomorodian, Z. S., & Shahrestani, S. S. (2024). An interactive assessment framework for residential space layouts using pix2pix predictive model at the early-stage building design. *Smart and Sustainable Built Environment*, *13*(4), 809-827.

Nabil, A., & Mardaljevic, J. (2005). Useful daylight illuminance: a new paradigm for assessing daylight in buildings. *Lighting Research & Technology*, *37*(1), 41-57.

Nas, D. S. (2021). *Aydınlatma Tasarımı Kriterlerinin Eğitim Yapılarında İncelenmesi; Cibali İlköğretim Okulu Örneği* (Master's thesis, Marmara Universitesi (Turkey)).

Natalia, S., & Suharjanto, G. (2022, Şubat). The openings and lighting design strategies of primary school in Jakarta. *IOP Conference Series: Earth and Environmental Science*, *998*(1), 012036. IOP Publishing.

Nezamdoost, A., & Van Den Wymelenberg, K. (2016). Sensitivity study of annual and point-in-time daylight performance metrics: A 24 space multi-year field study. *Proceedings of SimBuild*, *6*(1), 1–8.

Ngarambe, J., Adilkhanova, I., Uwiragiye, B., & Yun, G. Y. (2022). A review on the current usage of machine learning tools for daylighting design and control. *Building and Environment*, *109507*.

Sabbagh, M., Mandourah, S., & Hareri, R. (2022). Light shelves optimization for daylight improvement in typical public classrooms in Saudi Arabia. *Sustainability*, *14*(20), 13297.

Sorooshnia, E., Rashidi, M., Rahnamayiezekavat, P., & Samali, B. (2022). Optimizing window configuration counterbalancing energy saving and indoor visual comfort for Sydney dwellings. *Buildings*, *12*(11), 1823.

Tavşan, F., & Yanılmaz, Z. (2019). Eğitim yapılarında sürdürülebilir yaklaşımlar. *Sanat ve Tasarım Dergisi*, *(24)*, 359–383.

Uç, B., & Öztürk, L. D. (2022). Konutlarda hedeflenen aydınlık düzeyine göre gereken pencere cam alanının belirlenmesi. *Megaron*, *17*(1), 122–132.

Uysal, M. T. (2021). *A BIM based assessment of the impact of envelope design and building surrounding on the tradeoff between energy efficiency, thermal comfort and visual comfort* (Yüksek lisans tezi, Middle East Technical University).

Wirz-Justice, A., Skene, D. J., & Münch, M. (2021). The relevance of daylight for humans. *Biochemical Pharmacology*, *191*, 114304.

Yağmur, Ş. A., & Sözen, M. Ş. (2016). Dersliklerde görsel konfor ve iç yüzeylerin etkisi. *Megaron*, *11*(1), 49–62.