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Research Article

Control of Daylight in Educational Buildings with Natural Elements: The Case of Balikesir

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Abstract: In classrooms, where the learning process takes place and which cater to many users, indoor visual comfort and energy efficiency are essential for user health and academic success. Ensuring the homogeneous distribution of daylight indoors in classrooms is a significant problem that must be addressed during the design of educational buildings. To address this issue, designers use artificial elements such as shading and louvres in the building envelope. However, producing these elements results in carbon emissions, and they do not decompose naturally once their lifespan is over. Considering the United Nations Sustainable Development Goals (UN SDG) target of achieving net-zero emissions in cities by 2050, it is necessary to minimise emissions from these elements. Within this scope, the study aims to highlight the importance of landscaping in educational buildings to control the amount of natural light entering indoor spaces. Within the scope of the study, two identical classrooms at Balıkesir University Faculty of Architecture were examined. While there is no landscape area in front of the northeast-facing D1 classroom, there is a landscaped area with vegetation in front of the southwest-facing D2 classroom. The study examined the distribution of daylight in these classrooms during the day. It evaluated the effects of the landscape on the daylight performance of the interior spaces by conducting on-site point measurements with a light meter at 9:30, 12:30, and 15:30 on 21 June, the summer solstice. According to the measurement results, the northeast-facing D1 classroom had relatively high illuminance near the windows in the morning. In contrast, the D2 classroom had plants in front of its windows and had a homogeneous daylight distribution throughout the day. The study highlights that optimisation methods can be used in future studies to control the amount of daylight entering the interior of educational buildings through landscaping.

Keywords: *Daylighting, Daylight performance, Daylight performance in educational buildings, UN SDG 4, UN SDG 11*

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I. INTRODUCTION

A large portion of global energy consumption occurs in the construction sector. The situation is similar in Turkey (Ecoyfs et al., 2020). To reduce the energy required in buildings, the building envelope must be designed using energy-efficient strategies (Ghaffarianhoseini et al., 2016). In this sense, it is essential to determine the properties of building envelope elements during the design phase. The European Commission aims to make cities zero-emission by 2050 (Net Zero Cities, 2025). Using sustainable materials and applying natural solutions in buildings are essential in this context. In educational buildings that are heavily used during daytime hours when natural light can be efficiently utilised, proper building envelope design can minimise the need for artificial lighting elements indoors. Controlling excessive daylight entering classrooms is a challenge that must be addressed in educational buildings. Artificial elements such as louvres and shading elements are used to ensure that daylight enters the interior in a balanced manner. The production of artificial elements results in carbon emissions. Additionally, they do not decompose naturally when these elements end their useful life. The study highlights the importance of using natural elements in daylight admission into indoor spaces.

In Krarti's study in the United States, he adopted a simulation method to investigate the effect of glass types and window-to-wall ratios in buildings on indoor daylight performance. The study identified four different glass scenarios and four different window-to-wall ratios and simulated each glass scenario with each window-to-wall ratio scenario. The transmittance values of the glass scenarios identified in the study are 0.781, 0.505, 0.381, and 0.073. The window-to-wall ratio scenarios are 0.15, 0.30, 0.45, and 0.60. DOE-2 daylight simulation was performed on the specified scenarios. The results of the study are noteworthy. The results indicate that the best lighting performance is achieved with a transmittance of 0.781 and a window-to-wall ratio of 0.45. Although increasing the window-to-wall ratio improves indoor daylight performance, an excessively high ratio can cause glare and overheating in indoor spaces (Krarti et al., 2005). Manning adopted the measurement method in their study on the daylight performance of educational buildings

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in North Carolina. The study, which adopted measurements with daylight sensors in four different schools in North Carolina, took measurements in 5-minute intervals on weekends when schools were closed between August and October 2006. According to the results, the daylight during the day was sufficient in three schools under clear sky conditions, while the necessary conditions could not be met in one school. In addition, the homogeneity of indoor daylight distribution could not be achieved in schools. The study found that daylight was more homogeneously distributed in north-facing classrooms. The results emphasise the need for controlled daylight intake into indoor spaces in south-facing classrooms (Manning, 2006).

In their 2009 study, Ihm et al. aimed to investigate the effects of window-to-wall ratio and glass type in different regions on indoor daylight performance. In this context, the study primarily established a mathematical relationship between glass transmittance, window-to-wall ratio, and the total floor area of the area close to the exterior wall. Their study continued the DOE-2 simulation process in office buildings in 12 different regions. For model validation, they measured illuminance with a dimmer system in an office in Colorado and compared it with the simulation results. The validation indicated that the model is reliable and that deviations of ±4% are possible. The simulation results show that recommendations with high-transmittance glass and a high window-to-wall ratio can achieve savings of 60-64% in artificial lighting annually. The results also indicate that designs made with the mathematical model will give valid results, albeit with an error of 5–10. The study highlights the importance of computer-aided energy performance simulations in early design processes (Ihm et al., 2009). In 2014, Xue et al. aimed to examine the relationship between indoor daylight conditions and human behaviour in public buildings and residences in Hong Kong. The study surveyed 340 building users in Hong Kong. Cronbach's alpha reliability test was applied to test the reliability of the survey results. The study used regression analysis to reveal the effects of physical and behavioural patterns on daylight comfort. The statistical method shows that behavioural factors are more pronounced in moderately satisfied participants with daylight. In addition, the results indicate that external obstacles such as surrounding buildings negatively affect indoor visual comfort (Xue et al., 2014). Bellia et al. aimed to investigate the relationship between the physical parameters of lighting and user comfort perceptions in their study conducted in Naples. The study measured light levels, glare and Daylight Glare Probability (DGP) in three different offices in Naples. In addition, the study surveyed the offices to determine user satisfaction. The results of the on-site measurements and surveys were compared. The comparison revealed differences depending on the time of day and the current weather conditions. In particular, it was found that user comfort decreased during bright sunny hours or periods of heavy cloud cover. The study's results indicate that physical measurements alone are insufficient in evaluating daylight performance and that these measurements must be supported by user experiences (Bellia et al., 2017). In their study at a nursing home in Beijing, Yang aimed to investigate the satisfaction of elderly individuals with indoor natural lighting conditions. The study aims to compare physical light level measurements with user comfort perception. In this context, Yang adopted illuminance measurements, simulation and survey methods. The study was simulated using IESVE software. The simulation results were verified with illuminance measurements. The study results indicate that designs should be shaped according to the psychological and physiological needs of elderly individuals. In addition, elderly individuals have different daylight expectations in various spaces. For this reason, designers should adjust the level of daylight in interior spaces according to the purpose of use of the spaces (Yang et al., 2021).

Designers use Louvre systems and shading elements to control daylight entering interior spaces. There are many studies on this subject in the literature. In their study in Madrid, Gutiérrez et al. aimed to investigate the effect of Louvre systems with different surface properties on the daylight performance of interior spaces. In this context, they compared two types of ceramic surface Louvre systems with a traditional Louvre with a shiny aluminium surface. The study tested the effectiveness of these systems in an office building using a simulation method. Daysim carried out the simulation process. The study used the daylight factor (DF) from static metrics and daylight autonomy (DA) and functional daylight illumination (UDI) from climate-based metrics in daylight performance evaluation. The study results show ceramic material is a reliable and sustainable alternative. Additionally, ceramic louvres can balance aesthetics and functionality, making them both environmentally friendly and energy-efficient systems (Gutiérrez et al., 2019). In their study conducted in Lebanon, Galal aimed to investigate the effect of facade orientations on educational buildings' interior visual and energy performance under the Mediterranean climate. Another objective of the study was to scientifically evaluate Lebanon's building regulations requirement that the long facade of classrooms face south. Within the scope of the study objectives, annual daylight simulations were performed in classrooms with different orientations using DesignBuilder v6.0.1 and Climate Consultant 6.0 software. The study results found that daylight is distributed more homogeneously indoors in north and northeast-facing classrooms and that glare is less than in south-facing classrooms. Another important finding of the study is that heat gains are higher in south-facing classrooms than in north-facing classrooms. The study recommends that the law in Lebanon's building regulations requiring classroom facades to face south be reconsidered, considering differences between geographical regions (Galal, 2019).

Noshin et al. aimed to investigate the effect of light shelves on daylight performance in their study conducted in 2020. The study adopted a simulation method to examine the impact of light shelf slope angle, position, and height above the floor parameters on indoor daylight performance. Ecotect 2011 performed simulations for 21 June and 21 December under cloudy sky conditions. The simulation results show that the light shelf proposal, located 2.13 m above the ground

outside the building envelope and with a 20° inclination angle, provides the best visual performance. This proposal provided an 11.5% higher daylight illuminance level on 21 June and a 10.6% higher level on 21 December (Noshin et al., 2020). In their study conducted in South Korea, Lim et al. aimed to design shading elements that would control daylight penetration into the interior of residential buildings with a high window-to-wall ratio. The study selected four types of passive systems, namely Venetian blinds, horizontal louvres, light shelves, and egg crates, and measured both in-situ illuminance and temperature. In addition, the study performed energy simulations to evaluate the performance of the alternatives. The study results show that each system has different effects on indoor daylight performance and cooling load. In addition, the study stated that the egg-crate system effectively reduced the entry of excessive daylight into the interior and reduced the cooling load (Lim et al., 2020).

Marzouk, who aims to investigate the effect of skylights opened during the refurbishment of Omar Tosson Palace in Egypt on the daylight performance of interior spaces, has adopted a parametric optimisation method. The study aimed to balance the parameters of the rotation angle of the light directing element under the skylight, the distance between the elements, and the surface reflection properties. The objectives were spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE). In their study, GA maximises sDA and minimises ASE. The study results show that sDA increases significantly in the interior with light directing elements, and ASE decreases, increasing daylight illuminance and comfort levels. In addition, the optimisation results show that light distribution can be improved with small measures in the design (Marzouk et al., 2020).

Optimisation methods commonly used today are employed in studies to improve indoor daylight performance. In 2019, Shahbazi et al. aimed to maximise indoor daylight performance in offices and reduce the energy used in their research in Tabriz. In this context, the study adopted the optimisation method. The study determined parameters such as the window/wall ratio and shading elements characteristics for office facades. Useful Daylight Illuminance (UDI) and Total Energy Consumption (TEC) were the objectives. The optimisation process minimised UDI and TEC by changing the parameters through an algorithmic model. The optimisation process used Genetic Algorithms (GA). The study results show that the visual performance of the scenarios resulting from the optimisation increased by 75%, while energy consumption decreased (Shahbazi et al., 2019). Bahdad et al. aimed to achieve optimal visual performance in interior spaces by integrating light shelves in offices in Malaysia. The study adopted an optimisation method that was in line with its objective. Optimisation defined the characteristics of light shelves as parameters and the UDI daylight metric as the objective. Rhino/Grasshopper created the parametric model of the office, and Ladybug daylight simulations were performed for 21 March, 21 June, and 21 December. GA optimisation was carried out. As a result of the optimisation, UDI performance has increased compared to the current situation. In addition, the study states that considering indoor and outdoor shelf parameters together will positively affect indoor daylight performance (Bahdad et al., 2020). Khidmat et al. addressed educational structures in their study in Japan in 2022. The study aims to minimise ASE and maximise UDI by balancing the parameters of expanded-metal shading elements in classrooms. Grasshopper modelled the classroom parametrically, and the Ladybug plugin performed the daylight simulation. Octopus carried out the Multi-Objective Optimisation (MOO) process. The study obtained the best results from 3176 different design alternatives in optimisation. The best design received from the optimisation complies with LEED v4.1 criteria. In the best design proposal, the ASE value decreased by 100% compared to the current situation, while the UDI increased by 50% (Khidmat et al., 2022). Ziaee, on the other hand, addressed educational buildings in Tehran and Sari in their study. Ziaee aimed to improve daylight performance and thermal performance by balancing four parameters of light shelves to be integrated into classrooms: height, outer shelf length, inner shelf length, and angle position of the inner part. Rhino/Grasshopper parametrically modelled the light shelves in classrooms. Octopus carried out the MOO process. The study results indicate that using light shelves is more suitable in terms of visual and thermal performance in Tehran, which has clear sky conditions (Ziaee & Vakilinezhad, 2022).

Using natural instead of artificial elements to ensure a balanced and homogeneous distribution of daylight in the interior of educational buildings, which are heavily used during daylight hours, is essential within the scope of the UN SDG. This study investigates the effects of planting in educational buildings on indoor daylight performance. In addition, the study paves the way for future studies on optimising indoor daylight and thermal comfort through planting in educational buildings.

A. Problem Statement

Classrooms are communal spaces catering to large numbers of students between 8 a.m. and 5 p.m., facilitating knowledge exchange. Proper lighting design in classrooms contributes to visual performance and protects users' eye health, facilitating learning processes and positively influencing students' academic performance. Simulation and optimisation methods applied during the design phase of educational buildings can be used to determine the parameters that affect daylight entry into the interior space in the building envelope design. However, instead of using shading elements in front of transparent surfaces to prevent excessive daylight from entering the interior space, trees in the landscape design can be used. In addition to the homogeneous distribution of daylight in the interior, trees can also positively affect students' psychological state. Studies suggest using shading elements to ensure the homogeneous distribution of daylight in the interior. The study draws attention to natural elements as a priority to control the

distribution of daylight in the interior.

B. Purpose of the Study

The non-homogeneous distribution of daylight indoors in educational buildings is a challenge that must be overcome. This study aims to highlight the importance of landscape design in overcoming this challenge. In this context, the study examines two different classrooms at Balikesir University Faculty of Architecture, one facing northeast and the other facing southwest. While there is no landscape design in front of the northeast-facing classroom, there is a landscape design with different types of trees in front of the southwest-facing classroom. The study aims to compare the illuminance levels of the two classrooms by conducting on-site point illuminance measurements on 21 June, the summer solstice.

II. MATERIAL AND METHOD

Within the scope of the study, a search was conducted on the Web of Science, Elsevier, and Google Scholar using the keywords 'daylight, daylight performance, daylight performance in educational buildings, and daylight simulations.' Articles related to the subject were identified, and articles unrelated to the topic were excluded. In line with the UN SDG 2050 carbon-neutral cities project, the study aimed to highlight the importance of providing homogeneous daylight distribution indoors through greening in educational buildings in response to the increasing importance of sustainable materials.

Within this scope, the study examined two classrooms facing different directions at Balikesir University Faculty of Architecture, one with a landscaped view and the other without any landscape features. The illuminance measurement method was adopted using a lux meter to reveal the daylight performance of these classrooms within the scope of the study objective.

A. Balikesir Climate and Solar Radiation

Köppen-Geiger is one of the world's most widely used climate classification methods (General Directorate of Meteorology, 2023). Geiger states that there are 13 different climate regions in Turkey and that Balıkesir, the subject of the field study, has a Mediterranean climate type (CSA). Figure 1 shows the regions where the CSA climate type is found worldwide.

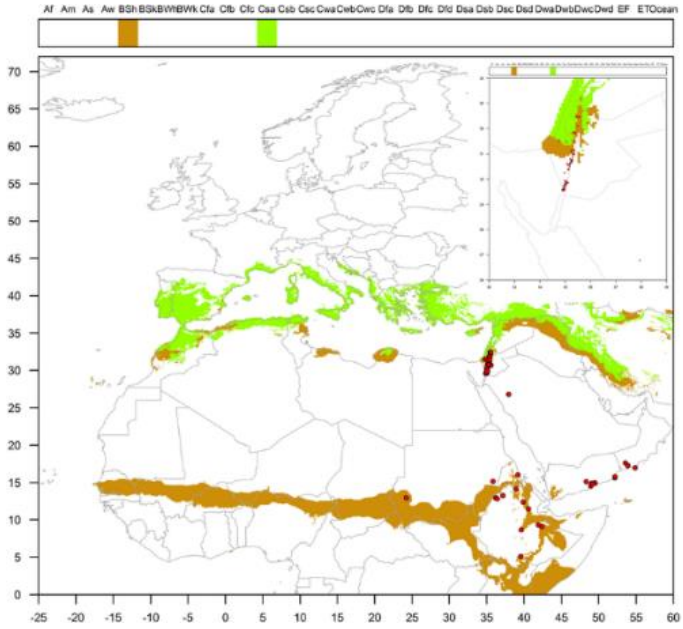


Figure 1. Regions where the CSA climate type is found (EFSA Panel on Plant Health (PLH Panel), et al., 2022).

Another factor that affects indoor daylight performance and influences design is the solar radiation of the region. Since Turkiye is located in the northern hemisphere, solar radiation decreases as one moves from south to north. The region with the highest solar radiation rate in Turkey is the South-Eastern Anatolia region. Additionally, water vapour in the atmosphere reduces solar radiation. The solar radiation of Balikesir Province, located at 39° latitude and 27° longitude, ranges between 1387-1534 kWh/kWp and is in the middle range. Figure 2 shows the solar radiation map of Turkiye (Atlim et al., 2019).

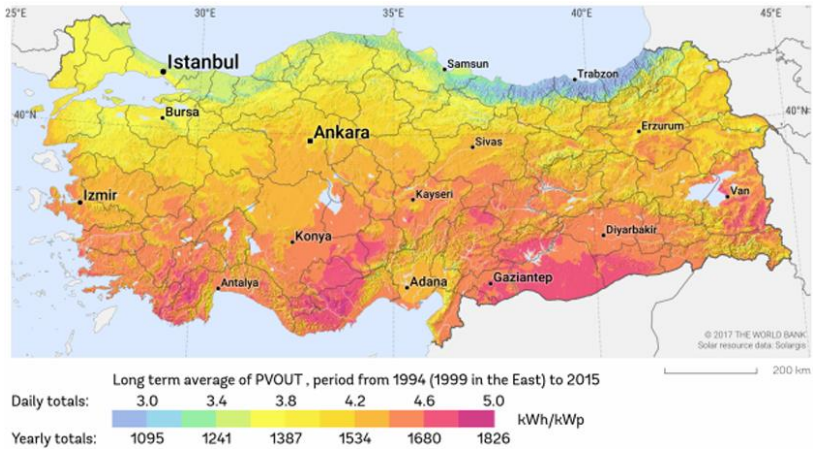


Figure 2. Solar radiation map of Turkey (Global Solar Atlas, 2025).

B. Case Study

The study examined two identical classrooms facing northeast and southwest at Balikesir University's Faculty of Architecture for fieldwork. Figure 3 shows the southwest facade of the Faculty of Architecture building. The eight-storey block on the right houses faculty offices, while the three-storey block on the left contains classrooms.



Figure 3. Southwest facade of the Balikesir University Faculty of Architecture building (Balıkesir site. (2013)).

Figures 4 (a) and (b) show the identical D1 and D2 classes where the measurement process took place. The classes are 6.94 m deep and 15.70 m wide. The D1 class faces northeast, while the D2 class faces southwest. While there are no landscape elements in the D1 class to control the entry of daylight into the interior, trees in front of the D2 class provide daylight control.



(a)



(b)

Figure 4. (a) North-east facing D1 class interior view and (b) Southwest-facing D2 class interior view.

C. Illuminance Measurements

Illuminance measurements obtain the amount of light flux falling on a unit surface area. The study adopted measurements with a luxmeter to determine classroom point illuminance values. The study conducted illuminance measurements within this scope using a Cem DT-1309 luxmeter at 9:30, 12:30, and 15:30 on 21 June 2025, the summer solstice, in two different classrooms (Figure 5). Luxmeter measurements were taken at a height 85 cm above the floor in a horizontal position.



Figure 5. Cem DT-1309 lux meter.

Horizontal and vertical grids with equal spacing were defined to perform illuminance measurements. Lux meters performed illuminance measurements at the intersection points of these grids. Figure 6 shows the measurement points in classes D1 and D2.

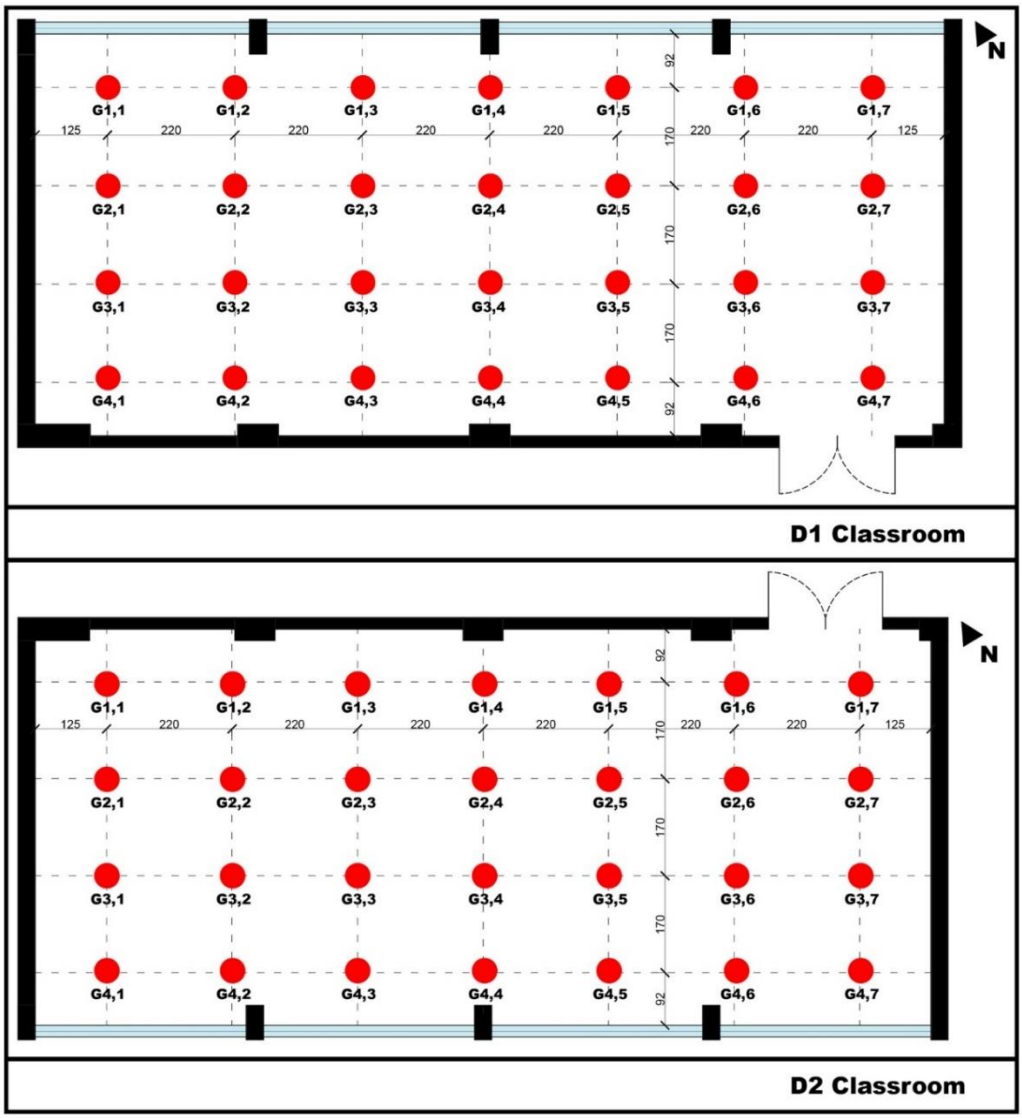


Figure 6. Measurement points in classes D1 and D2.

III. FINDINGS

The study conducted point illuminance measurements at 9:30, 12:30, and 15:30 on 21 June 2025, the summer solstice, using a Cem DT-1309 lux meter in D1 class, where there are no elements that block sunlight, and in D2 class, where the goal is to achieve homogeneous daylighting in the interior through landscape design. The study evaluates the illuminance values obtained from the measurements according to WELL standards. The WELL Standard defines the useful daylight range (UDI) as between 100 and 2000 lx. According to this standard, light levels below 100 lx and above 2000 lx are not considered in the evaluation (International WELL Building Institute, n. d.).

Table 1 shows the values obtained from the illuminance measurements taken by the study in classes D1 and D2 at 9:30 a.m. on 21 June. The measurements indicate that the illuminance level in the north-east facing D1 classroom is above the practical illuminance level in the morning hours. In particular, very high illuminance levels exist in areas close to the window. As one moves away from the window, the illuminance levels decrease. This indicates no homogeneous daylight distribution inside the D1 classroom in the morning. However, measurements taken at 9:30 a.m. in the D2 class show that the indoor daylight illuminance distribution is more homogeneous. The illuminance measurements taken at 9:30 a.m. in the D2 class did not yield values above 2000 lx. However, illuminance values below the minimum 100 lx were obtained at two points far from the window.

Table 1. Illuminance measurement results obtained at 9:30 a.m. in classes D1 and D2.

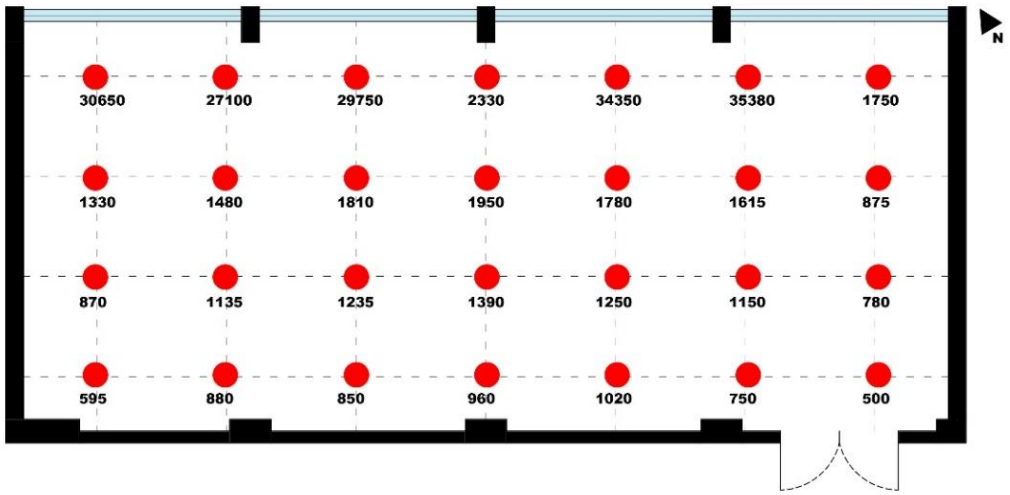
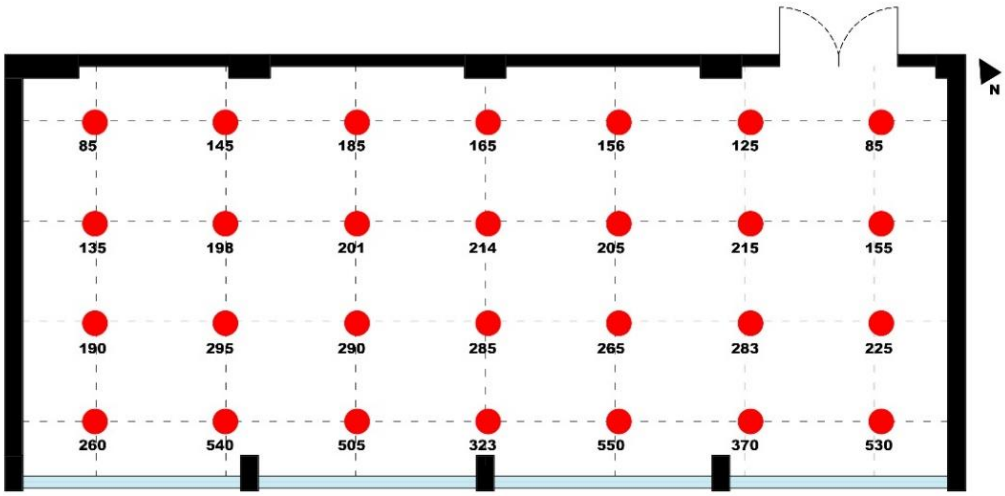
Classrooms	Measurement Results
D1 Classroom	
D2 Classroom	

Table 2 shows the illuminance measurement results at 12:30 in classes D1 and D2. Due to the sun's movement, illuminance values exceeding 2000 lx are not observed in areas near the window in class D1. In the illuminance measurements at 12:30 in class D1, the illuminance values of 28 points were obtained between 280 and 1435 lx. These values are within the acceptable range according to UDI. Illuminance decreases as distance from the window increases.

This indicates that daylight is not distributed homogeneously. In the D2 class, illuminance measurements at 12:30 PM yielded values between 156 and 1850 lx. According to UDI, these values fall within the acceptable range of 100–2000 lx. However, illuminance levels in areas close to the window are significantly higher than those farther from the window. This situation prevents the homogeneous distribution of daylight within the interior space.

Table 2. Illuminance measurement results obtained at 12:30 a.m. in classes D1 and D2.

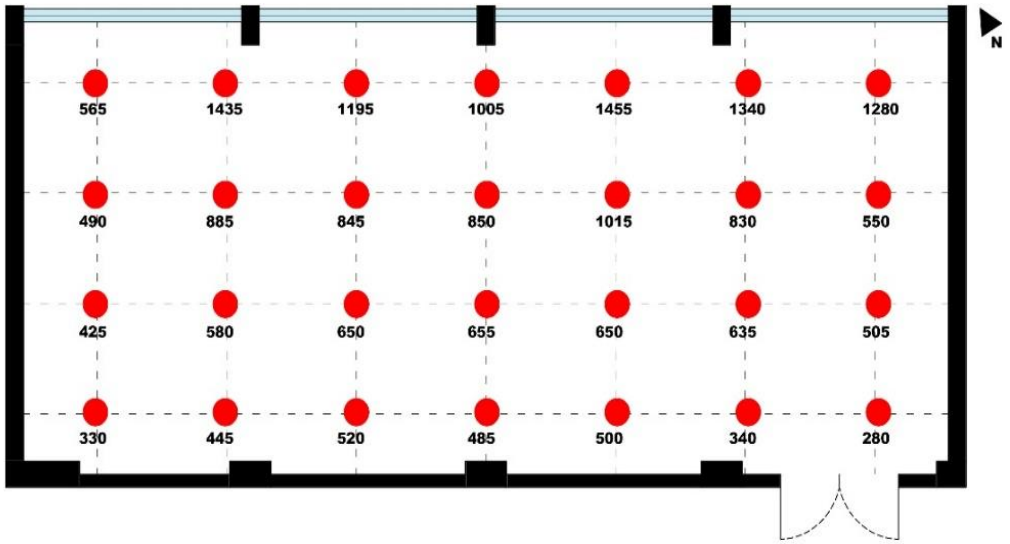
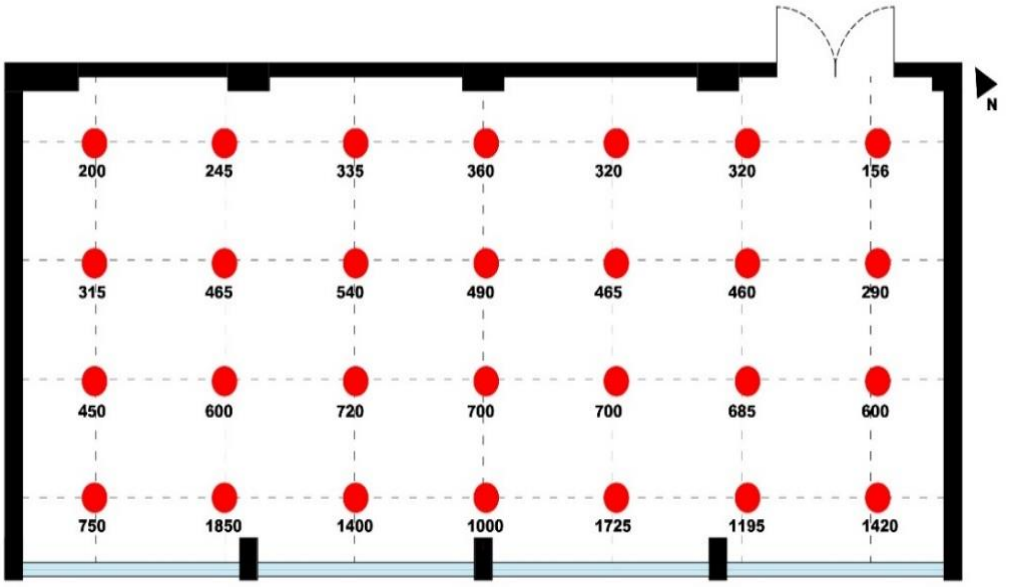
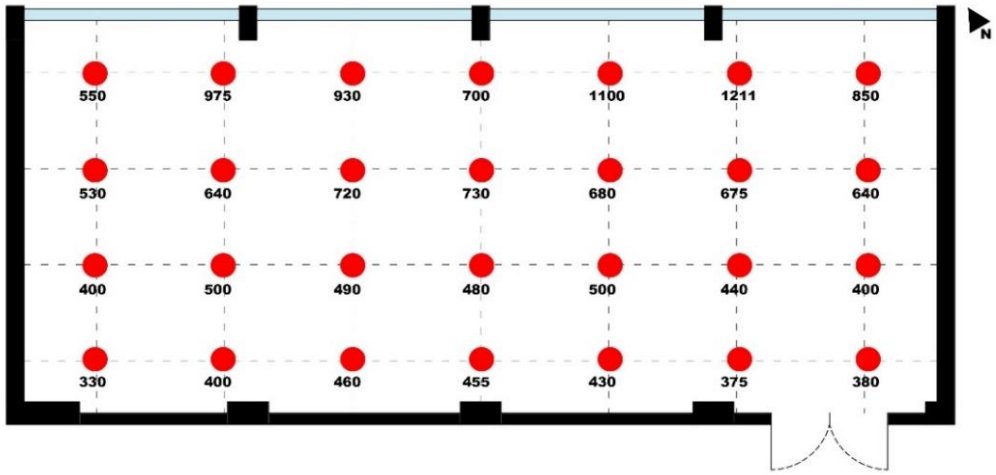
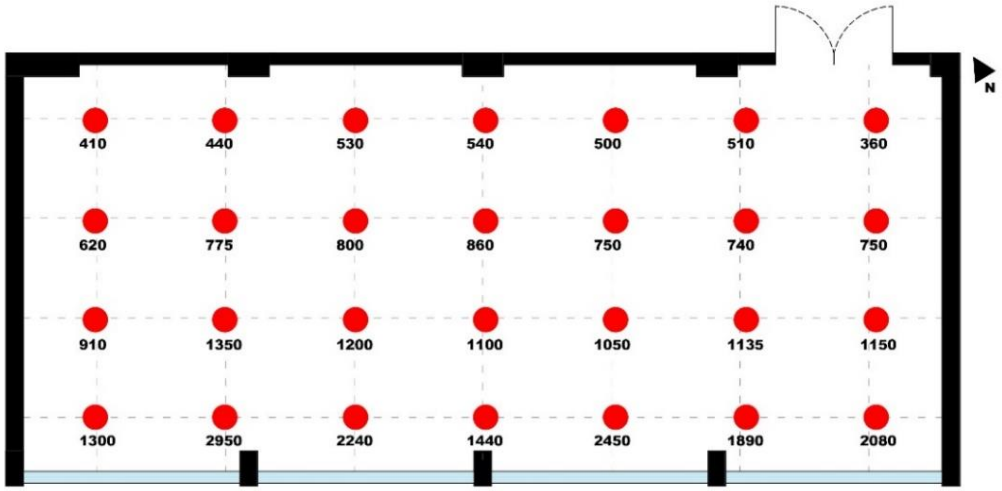
Classrooms	Measurement Results
D1 Classroom	
D2 Classroom	

Table 3 shows the illuminance measurement results at 15:30 in classes D1 and D2. The table shows that the highest illuminance in class D1 at 15:30 is 1211 lx, while the lowest illuminance is 330 lx. The illuminances measured at 15:30 are closer to each other than those measured in the morning and at noon. This indicates a more homogeneous distribution of daylight in this class during the afternoon hours. Due to the sun's movement, at 15:30, the sun affects the western regions more. Since the D2 class is south-west facing, higher illuminance levels are expected in this class, especially in areas near the windows. However, the trees in the landscape design in front of this class prevent excessive daylight from entering the interior and ensure that illuminance values are within the acceptable range (100–2000 lx) for UDI, except for three points. The illuminance values above the acceptable range are not as high as the 9:30 measurements in class D1.

Table 3. Illuminance measurement results obtained at 15:30 a.m. in classes D1 and D2.

Classrooms	Measurement Results
D1 Classroom	
D2 Classroom	

IV. CONCLUSION

UN SDG 4 argues that providing students with more comfortable and healthy environments in educational structures will facilitate the learning process and increase academic achievement. The use of artificial elements such as shading elements and louvres to bring daylight into interior spaces is frequently seen in the literature. However, UN SDG 11 aims to achieve sustainable cities and communities. In this context, the goal is to reduce city emissions, decrease energy consumption in buildings, and create sustainable environments. The production of artificial shading elements consumes. Additionally, these products harm the environment when they end their useful life. However, natural elements used to control daylight do not cause emissions and can be recycled. Within this framework, the study aims to highlight the importance of natural elements in enabling more homogeneous daylight penetration into interior spaces in educational buildings. As part of the study's objectives, illuminance measurements were conducted on 21 June, the summer solstice, in two identical classrooms within the Architecture Faculty building at Balikesir University.

Class D1 faces northeast and has no landscaping elements on its façade. Class D2 faces southwest and has plants on its façade. Point illuminance measurements were taken at three different times on 21 June. The measurement results are noteworthy. In the D1 class, measurements taken in the morning showed illuminance levels significantly above the beneficial range (100–2000 lx) according to UDI, particularly in areas near the windows. Additionally, there is no homogeneous distribution of daylight within the classroom. The study found that daylight is distributed homogeneously throughout the day in the southwest-facing D2 classroom. Without any measures to address the sun's movement, daylight illuminance would be quite high near the windows in the southwest-facing classroom, especially in the afternoon. However, it was found that the vegetation in front of the classroom allowed daylight to enter the interior in a controlled manner. The study highlights the importance of natural elements over artificial elements for achieving homogeneous daylight distribution indoors. Future studies could contribute to the UN SDG targets by using optimisation methods for landscaping in front of windows in high-rise buildings to improve indoor daylight performance.

DECLARATIONS

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Ethical Approval: This study does not involve human or animal participants. All procedures followed scientific and ethical principles, and all referenced studies are appropriately cited.

Plagiarism Statement: This article has been evaluated for plagiarism and no instances of plagiarism were detected.

Use of AI Tools: The authors declare that no Artificial Intelligence (AI) tools were used in the creation of this article.

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