BAU Journal - Creative Sustainable Development

Volume 5 | Issue 1
ISSN: 2789-8334

Article 2

May 2024

EXAMINING ELEVATION OPENING RATIO AND SPACE PROPORTIONS IN LEBANESE SCHOOLS

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building orientation, natural light, education institutions, room proportions, daylight

Recommended Citation

Traboulsi, Chirine and Felix, Mary (2024) "EXAMINING ELEVATION OPENING RATIO AND SPACE PROPORTIONS IN LEBANESE SCHOOLS," *BAU Journal - Creative Sustainable Development*: Vol. 5: Iss. 1, Article 2.
DOI: https://doi.org/10.54729/2789-8334.1123

EXAMINING ELEVATION OPENING RATIO AND SPACE PROPORTIONS IN LEBANESE SCHOOLS

Abstract

The academic performance and outcomes of students are significantly impacted by the architecture of educational institutions. When designing learning spaces, two important considerations are the size of the room and the elevation opening percentage that describe how much daylight enters the space through windows. Previous studies showed that these factors have an important effect on student learning performance. This study explores the link between elevation opening percentage and space proportions in educational institutions. In order to assess daylight dispersal in a classroom in Lebanon that faced north—the direction required for the nation's best solar exposure—a quantitative approach utilizing modelling software was employed. The investigation looked at four various room dimensions with ratios of 1:1, 1:1.5, 1:2, and 1:3, as well as six different height opening percentages varied from 10% to 100%. The simulations additionally demonstrated that the proportion of windows open has a noteworthy effect on natural light dispersion, with larger percentages leading to more uniform light distribution. The 1:1.5 space proportion is the most effective classroom ratio based on the simulation results.

Keywords

building orientation, natural light, education institutions, room proportions, daylight

1. INTRODUCTION

The architecture of educational infrastructure significantly impacts student academic achievement and outcomes*(Abdelatia, Marenne, & Semidor, 2010)*. Factors that shape learning spaces are proportion and percentage of elevation opening, or the amount of natural light entering the area through windows and skylights. These have recently been found to have a major impact on student learning outcomes (Abdel & Salama, 2021). Many room dimensions have, through research, been found to be more conducive to education, such as a length-to-width ratio of about 1.5:1 (Jia et al., 2023), The design of the classroom should also consider the amount of natural light to enter the classroom, as it has also been shown to impact the well-being of students *(Mirrahimi, Ibrahim, & Surat, 2013)*, productivity, and academic achievement *(Edwards & Torcellini, 2002)*. Productivity, and academic achievement. Better student performance and better academic achievement were found to be associated with the use of natural light in educational institutions.*(Baloch et al., 2020)*.

In Lebanon, according to Decree number 9091 issued by the Lebanese government on October 16, 2002, it's required that classrooms face south and laboratories face north along the long facade. This guideline of a Southern direction includes the whole Lebanese area, which potentially is inconsistent with all-climatic zones owing to the large diversity among the climatic characteristics, notably with regard to the Coastline area (Galal, 2019). Therefore, it is recommended that classrooms in the coastal area to be oriented towards the north and northeast (Galal, 2019). Additionally, daylight that derives from northern windows does not produce shadows; thus, it is suggested for classroom orientation as well as other educational spaces since it consists mostly of indirect light that diffuses emanating from the sky. Direct sunlight on north orientation may be received in only relatively brief durations in the beginning of the day or later in the day throughout the peak of summertime when educational institutions are closed (Al-Sallal, 2010).

Furthermore, the country has a distinct environment with hot summers and cold winters, which influences the quantity and spread of natural light as well as heating and cooling needs. As a result, it is critical to examine the connection between room dimensions and window apertures (Melki, 2013) in Lebanon's educational institutions in order to maximize natural light while also considering energy efficiency.

This research therefore seeks to establish the effect of room size and window opening percentage on lighting design in educational buildings in Lebanon. The study involves simulating the distribution of natural light in a total of four classrooms located on the Lebanese coastal region with different proportions (1:1. 1:1. 5, 1:10% 20% 40% 60% 80% 100%) oriented to the north, and with varying window sizes: 10%, 20%, 40%, 60%, 80%, and 100%). The purpose of this paper is (1) to (re) create natural light distribution in classrooms with varying proportions; (2) modify the proportion of openings for windows to analyze the impact on illuminance; and then (3) calculate the results to identify the optimal room dimension ratios for natural light in Lebanese classrooms. The findings of the study also provide understanding of the best room dimensions and window openings that offer maximum distribution of natural light in schools and the factors that affect it. The results of this study can be used to design safe school buildings in Lebanon and other countries that have comparable climates and construction techniques to improve students' performance.

1.1. Daylight and Its Importance in Educational Institutions

An up-to-date analysis on lighting conditions in classrooms revealed that certain levels of illuminance can enhance performance. This is particularly crucial in educational facilities, since even little differences in academic achievement can be magnified into significant discrepancies in future economic prosperity. School satisfaction, health-related behavior, and subjective wellness are vital variables that may additionally impact financial and academic achievement. Considering the significance of natural light for human physiology, mental health, and behavior, more research

should be done to determine how light affects human performance. Few research have sought to establish a relationship between illumination and academic achievement among youngsters in population-based research, and findings have revealed the favorable influence of daylight on academic achievement. According to some research, poor illumination in school classrooms may possess a significant impact on both children's well-being and learning abilities *(Baloch et al., 2020; Obralic & Jeghel, 2021).*

Another vital element of educational spaces is the spatial relationship and percentage of elevation opening which concerns the proportion of the room and the space admitting natural light through opening (windows or skylights) (Abdel & Salama, 2021; Baloch et al., 2020; Mirrahimi et al., 2013). Several recent studies have shown that both of these factors have a strong effect on the learning achievements of students. Research also shows that the natural light in the educational building offered various benefits to the pupils as sunlight can improve student performance, increase productivity, and improve the health of the student body (Samani, Samani, & Science, 2012). Other factors that can enhance the learning environment include proper interior space design and window placement that creates good daylight for the classroom (*Jia et al., 20*23) and leads to better student engagement and motivation and learning gains *(Abdel & Salama, 2021; Baloch et al., 2020; Mirrahimi et al., 2013).*

1.2. Student Outcomes and the Physical Educational Experience

Numerous studies have been undertaken to assess the efficacy of educational methods in enhancing students' academic performance. Multiple studies have discovered that the learning environment has a favorable impact on students' academic performance as shown in Figure 1. An environment that is beneficial to education serves as an incentive for fostering friendships, engaging in intellectual pursuits, collaborating with others, and providing support that promotes students' growth and learning *(Abdel & Salama, 2021; Al-Sallal, 2010; Baloch et al., 2020; Berry, 2002; Zaid et al., 2019).* For example, it was found that the quality of the physical learning environment such as classroom design, lighting and classroom acoustics was positively associated with students' wellbeing and learning. In particular, it is noted that classroom design does affect the conduct and social activities of students *(Jia et al., 2023; Mirrahimi et al., 2013; Samani et al., 2012)*. Studies also show that insufficient lighting in school classrooms can have a severe impact on children's health and learning abilities and that exposure to natural sunlight can improve cognitive function *(Baloch et al., 2020).*

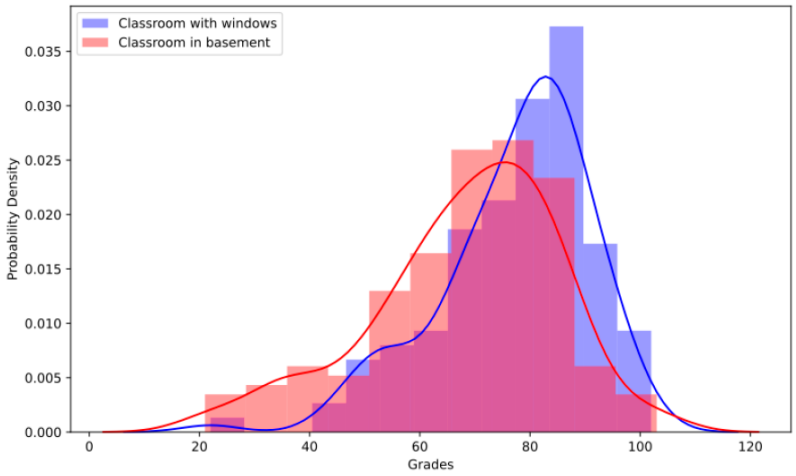


Figure 1 – Student results in classrooms with and without natural light (Porras Álvarez, 2020)

1.3. Design Considerations for Educational Facilities

The percentage of the room has a substantial influence on student learning outcomes (Obralic & Jeghel, 2021). Classrooms with a length-to-width ratio of about 1.5:1 have been proven to be more favorable to education. Moreover, classrooms with certain proportions, such as a 1:2 or 1:3 aspect ratio, have been demonstrated to increase learning results (Barrett, Davies, Zhang, & Barrett, 2015). There has been a recent study on the l between the percentage of opening of elevation and classroom proportions in educational institutions. The percentage of opening of elevation in educational buildings has a huge impact on the indoor environmental quality (Obralic & Jeghel, 2021), which can improve individual comfort, health, and academic performance (Fabi, Andersen, Corgnati, & Olesen, 2012). Furthermore, research indicates that there is the best range of proportion for elevation opening ratio with different rooms to maximize the benefits of daylight and minimize the negative effects at the same time (Abdel & Salama, 2021; Al-Sallal, 2010; Baloch et al., 2020; Jia et al., 2023).

Both of these parameters should be considered by the architects and designers since they are life-size in educational architectures. As natural light and space dimensions are important factors in educational buildings, architects and designers must ensure that these aspects are considered during the design process. The impact of these parameters on the indoor environment and students' performance may be estimated with the help of advanced building modeling tools (Manca, Cerina, Tobia, Sacchi, & Fornara, 2020). Designers can also consider implementing shade devices and light diffusers to control the quantity and intensity of natural light in the *room (Ziaee & Vakilinezhad, 2022)*.

1.4.The Effect of Window Size and Location on Natural Light Distribution

Window-to-wall ratio (WWR), as shown in Figure 2, has been one of the significant metrics to determine the amount of daylight entering a room. Many studies into the relationship between WWR and sunlight have already shown that the increase in WWR would significantly increase the daylighting levels in educational buildings. However, it is essential to not forget that an increase in WWR can lead to higher energy consumption due to increased cooling and heating loads.

Therefore, finding the appropriate balance between daylighting and energy efficiency is the key challenge (Albatayneh et al., 2021; Troup, Phillips, Eckelman, & Fannon, 2019).

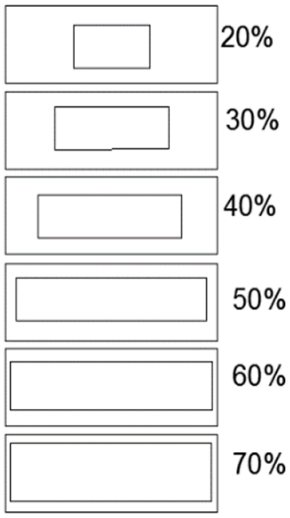


Figure 2 - Window-to-Wall Ratio and window position (Sayadi, Hayati, & Salmanzadeh, 2021)

Window size and location also play an important role in the process of natural light distribution in educational facilities. According to studies, higher positioned and wider windows give better dispersion of natural light while reducing glare and heat (Porras Álvarez, 2020; Wall, 2016). Another important factor in shaping the natural light distribution for educational facilities is the elevation opening percentage, or how much wall space is filled by windows. Increasing the elevation opening percentage could lead to more natural light and better student performance. *(Abdel & Salama, 2021; Manca et al., 2020; Obralic & Jeghel, 2021; Porras Álvarez, 2020; Wall, 2016).*

1.5. Natural Light in Educational Institutions in Lebanon

Lebanon is a Middle Eastern country with hot and humid summers and chilly winters, and there are major seasonal variations in natural light.(Melki, 2013). When it comes to the impacts of daylight on students' performance in educational institutions in Lebanon, it was found out that natural light has a positive influence on student mood and academic achievement. However, most educational institutions in Lebanon lacked sufficient direct natural light, and it is recommended building techniques such as increasing window size and shade devices that can be adopted to increase daylighting levels. Natural light has many benefits for students, including improved scholastic performance, but room proportions can affect student involvement and motivation. Another aspect that is quite significant is the relation of elevation opening percent in connection with room ratios in educational institutions. Increasing these parameters can help to improve indoor environment quality and as a result impact positively on the performance of students. Designers and architects should use the advanced techniques of building simulation to investigate these parameters and their effect on the indoor environmental quality and the student performance and should also consider the use of shading devices and reflectors in order to control the quantity as

well as the diffused light in the given room. Finally, the optimum proportion of the room and effective elevation opening percentage is crucial for educational buildings that aspire to create the most effective and beneficial educational environment for their students *(Al-Sallal, 2010; Baloch et al., 2020; Jia et al., 2023; Porras Álvarez, 2020; Porras, 2020)*

2. METHODOLOGY

It is in this regard that the theoretical approach identifies daylight and the importance of educational institutions, how it impacts the productivity and well-being of students, and the role of the shape of the space and opening size in daylight dispersion inside the classrooms. It also embraces the experimental method, represented by carrying out a simulation with the help of Autodesk Ecotect, a software tool for analyzing building performance—to investigate the effect of room proportions and elevation opening percentage on natural light distribution in educational buildings.

In order to select the most optimal scenario for a higher penetration and dispersion of natural light in a classroom in the coastal region in Lebanon, classroom models are created with four different room proportions, with aspect ratios of 1:1, 1:1.5, 1:2, and 1:3, all oriented towards the north. The window opening percentage is varied between 10%, 20%, 40%, 60%, 80%, and 100% to check how opening percentage and room proportions can influence natural light distribution in education facilities. Results are then compared and analyzed to present the most optimal scenario for natural light distribution in regards to space proportion and opening percentage in a Lebanese classroom located in the coastal region.

3. SIMULATION

Over recent years, daylight in educational institutions has been increasingly recognized as playing a vital role in enhancing the health, well-being, and academic achievement of students, as seen in Figure 1. In this regard, students exposed to natural light reported better levels of focus, higher attendance, and better exam scores, while showing lower levels of stress and exhaustion. (Heschong et al., 2002; Veitch et al., 2008).

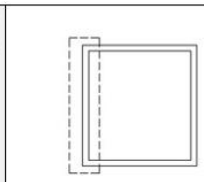
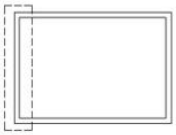
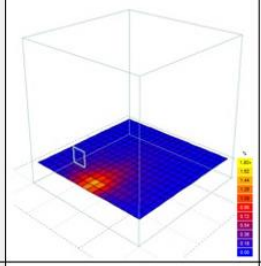
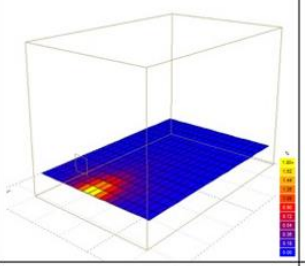
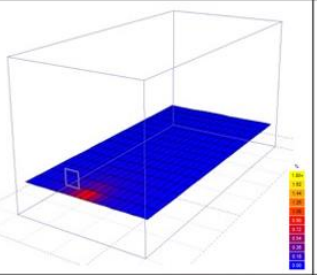
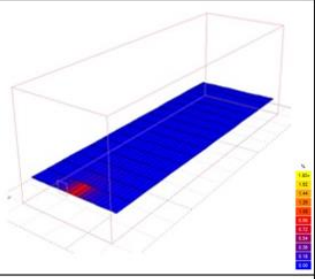
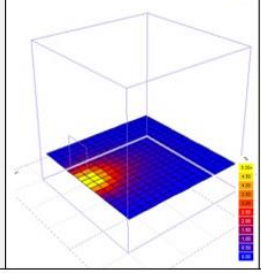
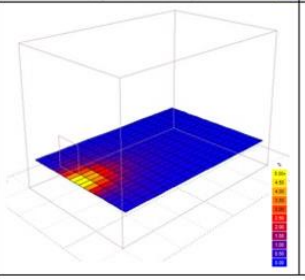
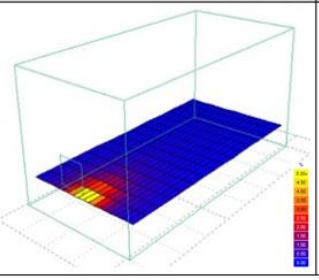
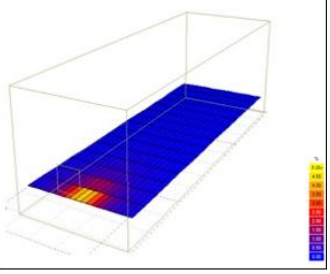
Obtaining an ideal natural light distribution in educational buildings, on the other hand, proves to be a difficult task dependent on various elements: building orientation, proportions, size and position of windows, shading devices, and climatic conditions. The interaction of such elements is able to significantly impact on the level and quality of natural light received by various regions of the structure, influencing the comfort and performance of the occupants.

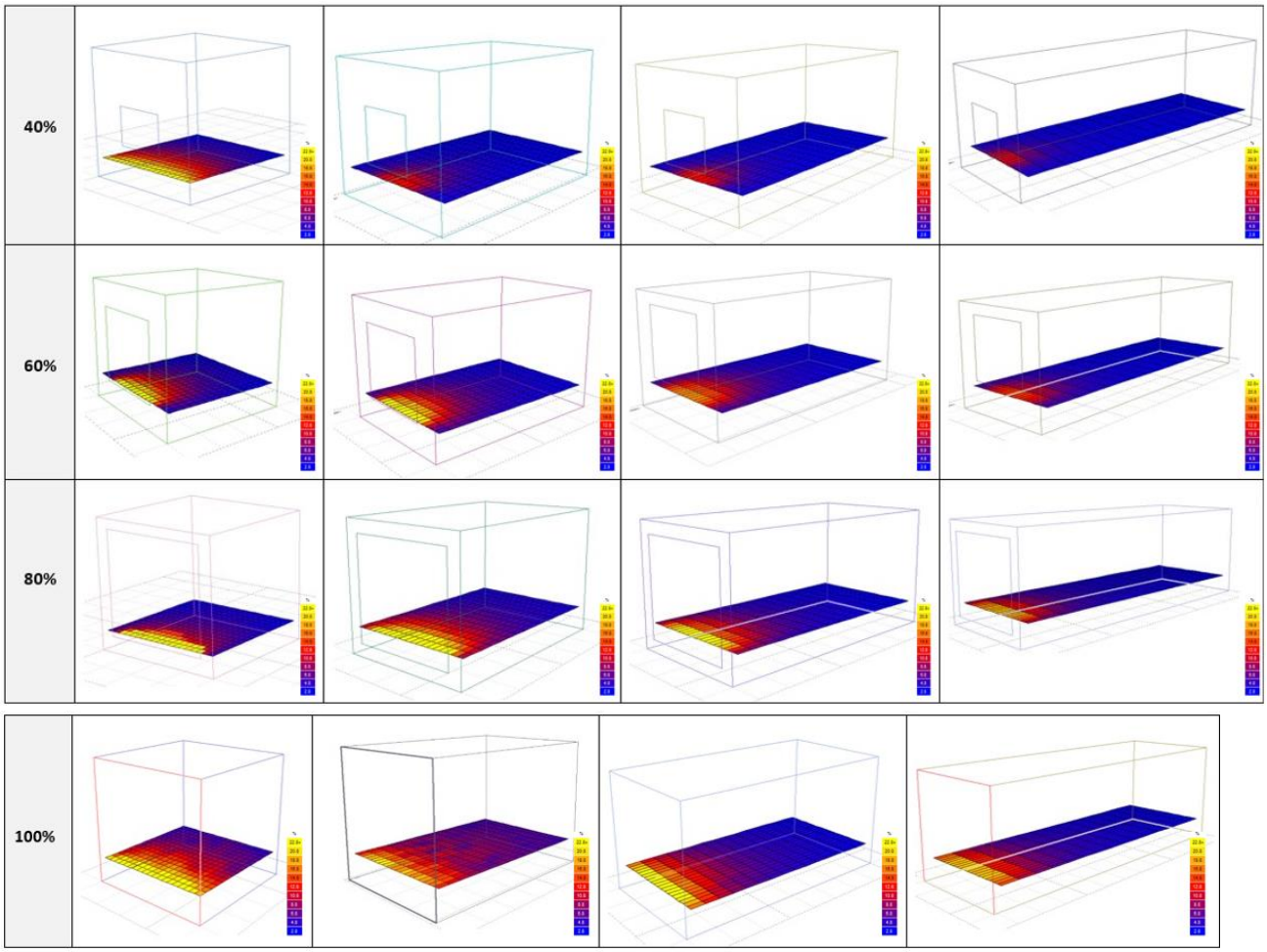
A simulation of a classroom with varying dimensions in the coastal zone of Lebanon was carried out to evaluate the influence of room proportions and elevation opening % on natural light distribution in educational institutions. As mentioned before, the selected classroom was orientated towards the north to avoid shadows and to promote indirect light that diffuses emanating from the sky. The distribution of natural light inside the classroom under various room proportions and elevation opening percentages as shown in Table 1.

The simulation's goal was to give insights into the best design parameters for improving natural light distribution in classrooms, resulting in improved learning environments for students.

4. RESULTS

Table 1 showing simulation results of different room proportions with various elevation opening percentage in a class (Authors, 2023)

Room shape				
Proportions	1:1	1:1.5	1:2	1:3
10%				
20%				



Natural light distribution models were performed on four various classroom proportions: 1:1, 1:1.5, 1:2, and 1:3 as shown in Table 1. The models were run with the window opening percentage changed between 10%, 20%, 40%, 60%, 80%, and 100% in order to determine how the opening percentage and room proportions affect natural light dispersal in academic institutions. The simulations were based on open clear skies with no shading devices or obstacles, and the classes were angled to the north to reduce sun gain. The simulations were performed at midday on the winter solstice, which is the time during which the sun reaches its lowest position in the sky in Lebanon.

Regardless of the amount of window opening, the findings revealed that the 1:1.5 proportion proved to be most efficient for distribution of light in classrooms. The 1:2 ratio worked well as well, with relatively increased illuminance levels in the rear of the classroom. The illuminance levels varied more significantly in the 1:1 and 1:3 proportions, with some sections of the classroom getting considerably less natural light than others.

The illuminance levels grew as the proportion of window opening increased. Nevertheless, this impact was rather evident in classes with less optimal proportions, specifically 1:1 and 1:3. The classrooms with the 1:1.5 and 1:2 ratios were less sensitive to the % of elevation opening, implying that such ratios seem to be more impactful for scattered light despite the opening size.

Shade devices and barriers, which are typically used in real structures to regulate the amount of natural light and solar gain, were not used in the simulations. The application of shading devices might enhance the efficiency of classes with less than optimum proportions even more. But even so, the use of shading devices would raise the expense of construction and upkeep, as well as have an effect on

the building's visual design. The results additionally demonstrated that raising the percentage of window opening can enhance illuminance levels, especially for less optimal ratios.

5. DISCUSSION

Table 2 showing the most optimal solution about room proportions and opening percentage (Authors, 2023)

Rank	Room Proportion(s)	Conclusions
Most Feasible Option	1:1.5	– Excellent consistency in illuminance levels throughout the space; – Displayed a more progressive and less noticeable reliance on opening dimension.
Second Feasible Option	1:2	– Maintaining high illuminance levels towards the inner space corners; – Displayed a more progressive and less noticeable reliance on opening dimension.
Unfavorable Options	1:1 & 1:3	– Greater variations in light levels; – Uneven distribution of natural light as some areas would receive less daylight; – Requires strategies to control the amount of daylight that enters the classroom.

As shown in Table 2, the results of the simulation showcase that room dimensions are considered an essential factor when defining overall lighting quality inside Lebanese classrooms. A development in light distribution efficiency was seen throughout the range of ratios studied. Classrooms with extreme ratios, such as 1:1 and 1:3, presented larger fluctuations in illuminance levels, reflecting the challenges related to incorporating daylight in spatially confined or overly elongated classrooms. These space proportions were more sensitive to changes in window opening percentages, causing certain areas of the classroom to receive much less natural light.

The 1:1.5 ratio was found to be the best scenario showing excellent uniformity in illuminance levels across the classroom. The 1:2 ratio showed impressive performance by maintaining high illuminance levels towards the back of the room under close observation. These two space proportions have shown adequate dispersion of natural light regardless of the size of the opening which reflects a consistent ability to disperse daylight into the space.

Various responses to modifications in window opening percentages dependent on room ratios were also noted. Classrooms with intermediate ratios, such as 1:1.5 and 1:2, displayed a more progressive and less noticeable reliance on opening dimension, which shows a potential in effective natural light distribution, independent of window opening percentage. However, classrooms with extreme proportions revealed greater adaptation to opening modifications and emphasizing the need for strategies to control the amount of natural light that enters these educational spaces.

Moreover, the simulations had six unique different opening percentages, which range from 10% to 100%. The results show that the percentage of open windows significantly affects natural light

dispersion, where the percentage open window results in a more even distribution of light through the classroom. Classrooms with higher opening percentages, especially in the range of 80% to 100%, had more constant illuminance levels than ones with smaller opening percentages, such as 10% through 30%. This shows a very important role for window size in optimizing natural light distribution and penetration across space. The larger the size of the window aperture, the larger the daylight intake, creating a more uniform illuminated environment that promotes visual comfort and fosters a variety of learning activities.

6. CONCLUSION

This study has investigated the relationship between window percentage and room dimensions, specifically in schools, with a focus on natural light distribution. In the study, four classroom models are on the coast of Lebanon with different proportions (1:1, 1:1.5, 1:2, and 1:3) oriented to the north, and with window percentages changing from 10% to 100%, we seek to investigate what are the most efficient room dimensions in the distribution of natural light.

From the results of the simulation, the 1:1.5 ratio gives the best result for optimal natural light distribution, the 1:2 ratio is the second best, and the 1:3 ratio has the worst illuminance. In addition, increasing the ratio of window openings was found to have a positive impact on natural light dispersion, although this should be balanced by the need to avoid glare.

These results put forward important implications for architects and designers working on educational buildings in the coastal zone of Lebanon and other similar settings. Paying close attention to room dimensions and window location and size will be able to enhance natural light dispersion and foster a better learning atmosphere for students.

It is further critical to acknowledge a few weaknesses of the study, such as the reduced modeling assumptions and absence of thought to shading devices or obstacles, since their impact on natural light distribution in educational buildings was not taken into consideration. It also did not explore the impact of glare, which further contributes to its shortcomings. Glare, an excessive brightness or a contrast in the visual field, could have a big impact on visual comfort and work productivity in educational settings. Further studies can be done to expand on this study in investigating the effects of shading devices and other design techniques on natural light distribution, including the effects of natural light on student success and welfare.

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