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# Effects of Design Openings Elements on Energy Efficiency of Educational Buildings at the University of Mosul

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## Abstract

The educational buildings in the University of Mosul are considered energy-consuming buildings due to a high density of users, working hours, and the construction situation. Natural lighting is used to reduce energy consumption, which depends on the openings system of the interior space. Lacking clear strategies for designing windows to provide natural lighting and reduce energy consumption, this research aims to develop a guideline of the strategies and characteristics of openings in educational buildings in the University of Mosul to provide natural lighting, reduce energy consumption, and provide comfortable interior spaces. A mix-methodology was adopted using quantitative and simulation methods applied to achieve the objectives. Visual observation with a checklist was used to observe the buildings and collect data related to the window in existing buildings. The questionnaire was applied to 246 respondents. The simulation technique used the "Design Builder" application to build the virtual model of the case study "the Faculty of Environmental Sciences and Technologies" based on visual observation data. Results of the questionnaire were used to create two models, the existing and modified building. The results showed that most of the energy consumed is located in student spaces. The student space consumes over 60% of the energy for lighting compared with the new model, which reduces energy use to 45%. The results showed the effective proportions windows in classrooms are 20%, administrative, teaching spaces 25%, and student spaces and corridors 65%.

**Disciplinary**: Green Architecture (Interior-Environment), Energy Science & Sustainability, Built Environment.



## Cite This Article:

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# 1 Introduction

Natural lighting is applied in education buildings in many forms to obtain the best lighting in interior spaces. However, many building users rely on industrial lighting to illuminate interior spaces, which increased energy consumption. Thus, scholars try to find methods and strategies that depend on clean and friendly energy considering the health, psychological and economic factors. Prolonged exposure to artificial light is harmful to health, except in large buildings with deep spaces, which is difficult for natural light to reach part of the space away from the windows. However, modern lighting methods, such as light tubes and reflective shelves usually used to conserve energy and create a healthy environment (Javadnia, 2016). This study finds the optimal window characteristics with adequate natural lighting to decrease glare and heat gain.

Moreover, finding the balanced relationship between the design of the windows and their effectiveness in reducing energy consumption and providing lighting comfort. Using natural lighting is not a new concept and continues to be a goal of the entire community, particularly architects. The window is the main natural light source for interior space that the designer tries to keep windows out of direct sunlight, which depends on the nature of the interior space. Several studies have determined how to introduce natural lighting to provide comfort to users, eliminate the effects of daylight, and limit artificial lighting. Lighting is one area that researchers consider from the materials that can help reduce energy consumption, which received significant attention due to their inherent properties to respond to changes (Husein et al., 2020).

The University of Mosul includes many buildings that use artificial and natural lighting at varying values. Energy consumption of artificial lighting in the UoM is about 40% of the total energy consumed per year. This ratio highlighted the importance of finding the best strategy for using clean energy for solar radiation to light the university buildings' interior spaces. Educational buildings (colleges and scientific departments) are the largest consumer of energy in the university, due to several reasons, including the size of the buildings, the number of users and the period of work, and the fact that these buildings were established in different periods without considering the importance of energy conservation and clean energy. The lack of laws and guidelines for the efficient use of natural lighting that reduces energy consumption and provides light comfort to users is one of the most important research motives, especially for the University of Mosul, which will start to follow the global trend for sustainability and considering the principles of the environmentally friendly buildings.

The main research objective is to develop a guideline for strategies and characteristics of the window in educational buildings in the University of Mosul to provide natural lighting, reduce energy consumption, and provide comfortable interior design. Sub-objective related to the main objective created. Each objective is linked to specific methods to measure it and achieve the main objective.

- Determining the design strategy for providing natural lighting for interior spaces in a way that leads to a reduction in the energy consumed in industrial lighting.

- Finding the ratio and specifications of window openings in educational buildings to ensure efficient use of energy.
- Determine the psychological and physical needs of users in designing window openings in buildings in a manner that ensures efficient use of energy.

The research focused on studying the strategies of designing windows in the most energy-consuming educational buildings in the University of Mosul "Faculty of Environmental Sciences and Technologies". The area of research is the energy efficiency of the lighting and the visual comfort of the interior spaces in the selected building. Moreover, the physical characteristics of the windows are included in the framework of the study.

# 2 Literature Review

## 2.1 Strategies for Designing Openings to Provide Efficient Natural Lighting

Saleem (2009) indicated the importance of specifications for designing windows in architectural spaces to achieve appropriate and efficient natural lighting levels and indicated suitable spaces for windows in architectural spaces in the city of Baghdad. The study relied on finding the appropriate area to reduce the artificial lighting according to the different jobs and occupants (Saleem, 2009). Szokolay (2008) also indicated that window design is affected by important factors, which are (glass penetration factor T) and (window frame factor F), and (window maintenance factor M). The “window-to-wall ratio” (WWR) is known as Transparency Rat. Windows affect users’ comfort and classroom power requirements in two main directions (West and East). A building was selected for a case study during the design phase. Study one class facing east and another class is facing west. With the help of DIALux Evo 6.0, DesignBuilder 5.5 and Energy Plus 8.9 software for lighting and energy simulation, two semesters were simulated. The results show that in addition to providing more comfortable conditions, a 50% glazing rate will reduce the need for artificial lighting by at least 15% (Ashrafian & Moazzen, 2019).

Different window locations and orientations affect the energy consumption of a typical room in an office building in a hot climate in Cairo, Egypt, are studied. This case study aims to analyze and achieve the good environmental performance of building space and assess its impact on the natural light that Energy Plus requires. The study concluded that a 20% WWR (window-to-wall ratio) facing west consumes 25% less energy than a 3: 1 rectangular pit facing west. The upper hatch has the highest light intensity, as it covers about 50% of the room area. The rectangular 3:1 top hatch in Northern Europe consumes 30% less energy than the rectangular 3:1 bottom hatch at the interface. The top hatch is best suited for natural lighting in light intensity, as the light covers more than 60% of the room area (Azmy & Ashmawy, 2018).

## 2.2 Integrative Relationship between Window and Energy Efficiency

Amaral et al. (2016) measured parameters for optimal window size. First, evaluate the parameters of opening type, direction and size. Second, one of the most popular windows in

Portugal was used to assess the effects of the hood. The thermal evaluation is performed by calculating the hours of discomfort using dynamic simulations. The results showed that in the northern direction of the site, the three-layer glass performance is better than that of the single-layer and the double-layer glass. Regardless of the type of window, the worst opening directions are northeast and northwest. Note that the optimal window size does not mean that the cooling and heating requirements are equal. The overhangs improve the room's thermal performance significantly. However, it allows the windows to have a wider time interval within the permissible size range without affecting the performance.

Javadnia (2016) showed that modern architecture in Iran depends entirely on artificial lighting, which leads to large energy consumption for indoor air heating from artificial lighting, using tube light which is widely used in developed countries. This system consists of three parts: collector, outlet, and diffuser. Sunlight enters the room through a cylinder. A cylindrical structure of aluminium covered with silver with a high reflection coefficient installed on the surface to direct sunlight and prevent the entry of dust particles and another transparent cover installed in their room at the same level as the ceiling and connected to the cylindrical body to scatter the light in all directions inside the building. It causes a steady column of air to be inside the cylinder. This air column acts as an insulator and prevents hot air inside the building and hot air exit in winter. The light tube is also effective on sunny, cloudy, and even rainy days (Javadnia, 2016). The system uses the concept of applying new energy (solar energy) by reflecting and condensing daylight and sunlight in an aluminium cylinder with a mirror cover of pure silver (Javadnia, 2016).

Yang et al. (2015) used DeST to create and analyze three simulation models Chongqing, Shanghai, and Wuhan, to evaluate the optimal windows to walls ratio and types of glass in each direction for the residential buildings air conditioning system under different operating conditions in three model cities in hot summer and cold winter. The study analyzed changes in annual heating energy demand, annual cooling energy demand, and total annual energy consumption under different conditions (including different trends, usage patterns of air conditioning system, window glass ratios and window types). The results show that when the percentage of window walls also increases, the total energy consumption increases. It is most pronounced when the direction of the window is east or west. In terms of energy efficiency, Low-E glass has better performance than insulating glass. From this study, the effect and sensitivity of the window-to-wall ratio on the total energy consumption are related to the operating pattern of the air conditioning system, the orientation of the exterior window and the type of the glass window (Yang et al., 2015).

## 2.3 Comfortable Lighting Level in Educational Buildings

Ajami and Alwan (2012) indicated the importance of natural lighting in the internal environment of learning spaces on the operational efficiency of the space and the comfort of the users of the space. It also confirmed that lighting is one of the factors for the operational success of space. The study found that the number of windows and their area is qualitative influences the psychological comfort and lightness of the educational interior space if it matches the design standards for natural and industrial lighting. So there must be artificial lighting in the spaces, and it cannot be dispensed with, but it can be reduced (Ajami & Obaid Alwan, 2012). Adopting artificial lighting on its part, in light of the lighting of the place, can cause an increase in the proportion of mental and physical illnesses and depression and delay the patient's recovery. Nowadays, natural lighting activates people's interest in introducing them into buildings, especially when their properties become Clear in pursuit of sustainable construction as a source of renewable and environmentally friendly energy. Various surveys confirmed that students' and teachers' learning/teaching performance and health conditions depend largely on the quality and quantity of sunlight and indoor temperature conditions. Using natural light in educational buildings aims to reduce energy consumption and costs, but student performance must also be improved. Proper window configuration can reduce glare, light distribution and sunlight control, thus improving visual and thermal comfort.

De Giuli et al. (2015) searched for indoor environmental conditions and children's comfort in 8 classrooms in three primary schools in Italy; this is an evolution of the author's earlier experimental research in other educational buildings. Make immediate and long-term measurements to assess climatic conditions (i.e. temperature, relative humidity, carbon dioxide concentration, and light). Three questionnaires were distributed to verify students' perceptions of thermal comfort and lighting, satisfaction with factors related to construction, and interaction with the environment. The expected score and the expected percentage of dissatisfaction indicators were calculated, and an adaptive method was adopted. However, the results did not match the self-evaluation of thermal comfort by the students. An innovative multivariate classification method has been developed as a potential building inventory assessment tool for identifying the focus of repair, maintenance, and renovation. Students complain about the thermal comfort and the penetration of sunlight in the hot season. In addition, construction and psychological factors for the school with the worst climatic conditions in the local area were evaluated (De Giuli et al., 2015). This study aims to demonstrate that the quality of the school environment greatly influences students' academic performance. The ergonomics factor is low lighting, which plays an important role in visual tasks, leading to visual comfort or fatigue. This research presented the results of determining lighting profiles for the selected university course. Specifically, it focuses on detecting the daylight factor, which is an important factor for the amount of daylight in the classroom; its value is a relative amount and depends on the correct spatial layout of the classroom. The search results show that the value of this indicator is insufficient. Finally, with this program, the solution could replace artificial lighting in the classroom, and it is a potential alternative to improve the visual comfort of the classroom (Tureková et al., 2018).

The conceptual framework is formed by considering the case study of this research. Therefore, the physical characteristics of the windows as the main factor in reducing the energy consumption for lighting. This factor included three variables (Figure 1), which each one included sub-variables and values used to build the tools of measuring in the methodology part.

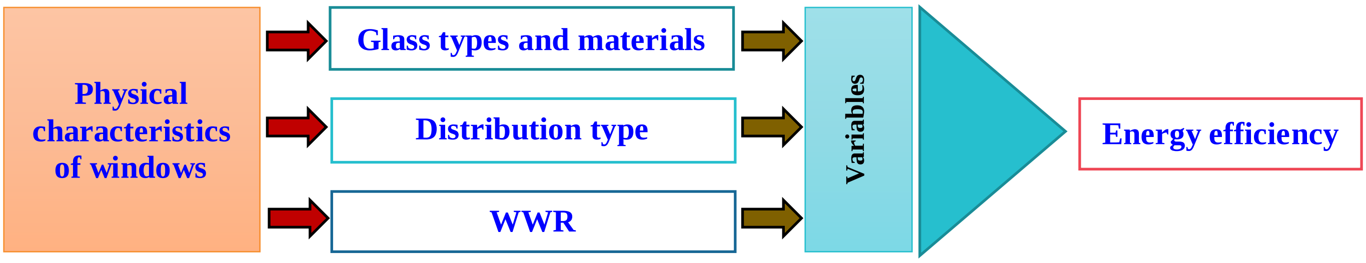


**Figure 1:** The conceptual framework.

## 3 Research methodology

This study approach is a mixed-mode methodology (quantitative with simulation), including three steps of data collecting and analysis. **The first step** is to justify the case study according to five criteria used to design an observation sheet and checklist to narrow down and select the case study. The five criteria are: (Building type, Area of building, Users density, Energy Consumption, The applying of the energy efficiency). The observation sheet and the checklist are designed to document the necessary information of the buildings during the site visit using visual observation. **The second step** is to organize a survey for the users (sample size 246 respondents) in the selected case study at the University of Mosul. The survey included three types of questions. The first type of question is general information about the respondents. The second type is related to Physical characteristics, visual and psychological comfort, which included five questions. The third type of question is related to the preferences of the Window area, proportions, location, and position in the wall. The result of this step will provide the preferences of the type and physical characteristics of the windows, which are used to build the virtual model of the building to modify and simulate the result of modifications, which is the last step of collecting data. **The third step** applies the users' preference and modifies the windows in the virtual model to match the characteristic of windows to provide natural lighting and reduce the energy used in artificial lighting. The selected case study from the University of Mosul simulated to compare energy consumption results based on the data from the existing site. Moreover, the questionnaire results to build two models, an existing and modified building whose window openings were redesigned. The results were obtained from the two models using the Design-Builder program to produce the final results.

## 4 The Case Study Building

After applying the criteria of selecting a case study, the case study is an education building related to the "College of Environmental Technology – University of Mosul". The survey helps the researcher find the focus point of the physical characteristics of the windows in the educational building in the University of Mosul, which are a ratio of the window to the wall are the position of windows on the wall glazing type. Design builder software was used to build the existing and modified model of the case study to determine the optimum window size ratio in the internal walls of the College of Environmental Technology rooms, classrooms, student space, lecturer rooms, cafeteria, and labs, see Figures 2 and 3. This software contains an Energy Plus analyzer engine that can calculate solar heat gain and energy consumption related to loading, heating, and cooling. Building simulated in Design Builder software to determine the optimum percentage of window size on building exteriors. A luminance level used 500 Lux based on the ASHRAE standard.

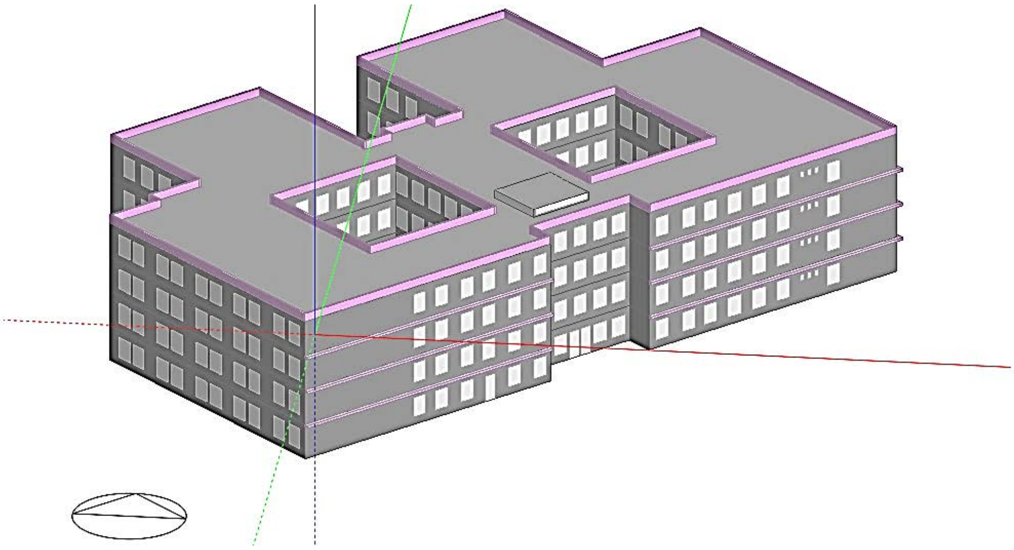

**Figure 2:** Model for existing building (case study).

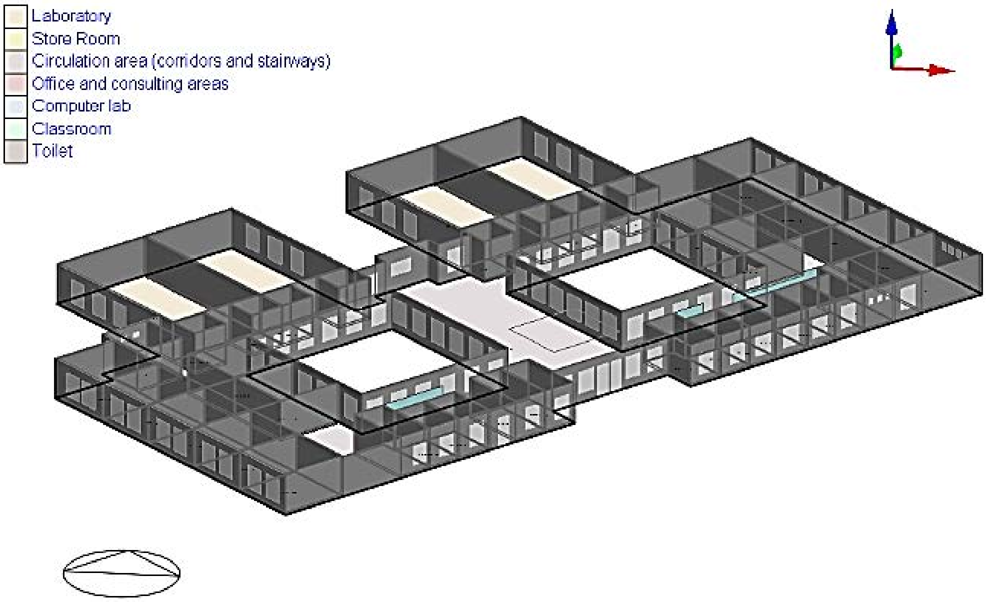


**Figure 3:** The ground floor of the case study.

Building facades window-to-wall ratio was examined according to the building users' opinion, and it ranges 30-50% with a proposed action. For multiple windows, a 30% glass model is considered to measure the number of windows with the change of the type of glass material and the extent of its impact on energy consumption. Then, compare the results with the reality of the situation, compare these proposals, clarify the temperature difference of the interior space, and weather data details average temperature, bag throughout the year, and on a specific day, 15 January. The effect of lighting has been neutralized in these treatments, which can conduct future research to determine the effect of the amount of lighting in the case of multiple or continuous windows.

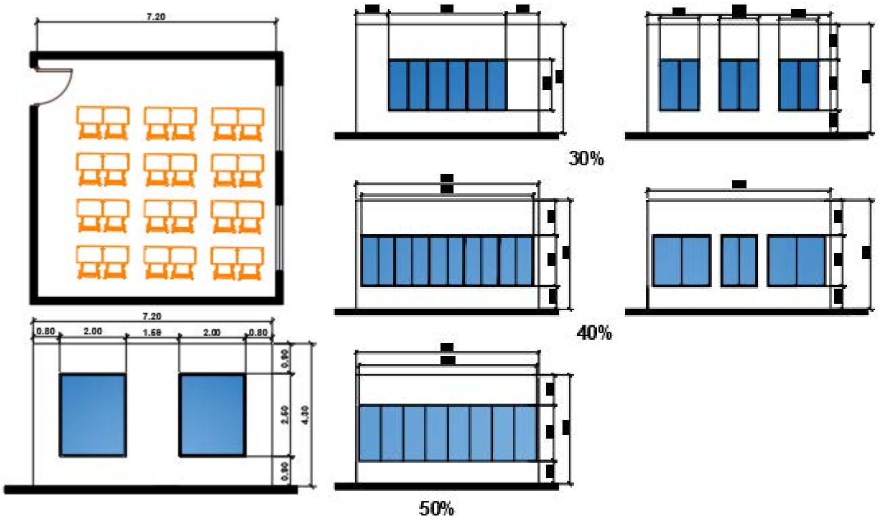


**Figure 4:** Glazing system combinations scenarios and sizes.

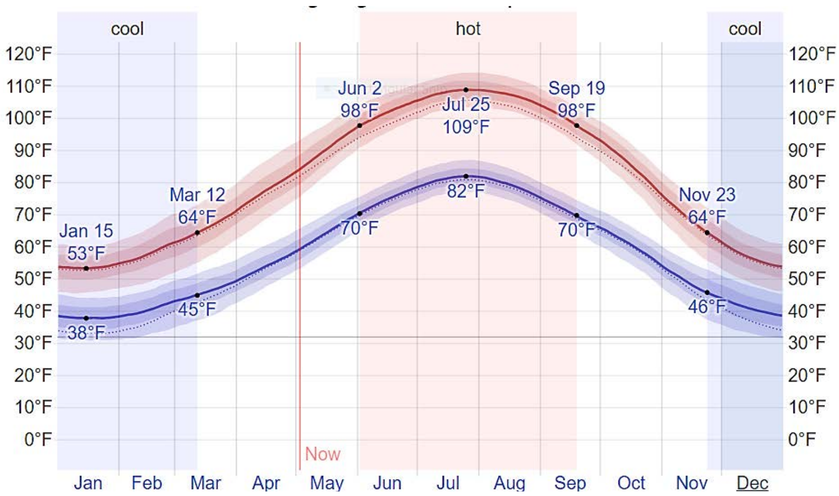


**Figure 5:** Average High and Low Temperature (source: https://weatherspark.com/y/102754/Average-Weather-in-Mosul-Iraq-Year-Round).

## 5 Result and Discussion

The survey results show that the important interior spaces that need natural lighting are 24.5% for student spaces, 30.6% for classrooms, 20.4% for the cafeteria, and 14.3% for the library. The results indicated the relationship between human needs and space needs, in which most of the space selected by the respondents are functional spaces where users spend most of the working and rest time on it. Most respondents select classrooms, student space, and the cafeteria as the most important spaces with a high glazing ratio.

A simulation of the building created depends on the questionnaire's results distributed to the occupants of the building, which indicate the preferred proportions. These preferences proportions are used to construct modified models. Each model treated a case. The majority of the respondents select the multiple windows type, which multiple windows with Dbl LoE glass drop from 31.1°C to 26.3°C. The ratio of reducing the energy consumption, in this case, can provide suitable lighting comfortability for the users, which continuous windows can create a good value of natural lighting. However, the users of the interior space will be unsatisfied. The balance between the windows type, users satisfaction, and energy consumption can create a perfect interior environment in education buildings, specifically in quiet zones and rooms. The other interior spaces such as student space, entrance, and cafeteria, most of the respondents (74%) preferred the continuous windows with WWR more than 50%, which reduced the energy for artificial lighting to 31% but raised the energy consumption for the airconditioning in the same time.

The modification results in the case study led to reducing the amount of energy consumption, represented by 50% as the highest rate from overall treatments, followed by a 30% reduction with multiple windows modification. The increasing energy consumption follows the increase of the window area and the continuous type due to heat gain resulting from increased window frames and the glass type, see Table 2. Figure 6 shows the temperature after using each modification case throughout the day, which is considered a summer day where higher interior space temperature is observed. Table 1, temperatures were compared between the selected cases. The results show that at a 30% WWR ratio in case 2, the temperature was 1.6% higher with multiple windows than continuous windows and the same glass type. However, double glazing shows a drop of 2.33% in the interior temperature from 27.0°C to 24.7°C. Results from simulation for using Double glazing (Dbl LoE) show a significant effect in reducing energy consumption by reducing the gain and heat loss. Dbl LoE (e2 = .1) Clr 3mm/13mm Air) to 264.92 kW/m$^2$, which reflect the ratio of 8.46%. The comparison between the selected cases shows two solutions to reduce the energy consumption in case no.2 that used a glazing ratio of 30% with continuous windows, and case No.5 with a glazing ratio of 30% with multiple windows. Results indicate an increase in energy consumption in the case of multiple windows, wherein case 2 was 264.92 compared with case 5 (269.01), the rate of increase was 1.5%.

**Table 1:** Details of the air temperature (°C) for each case study with cooling

| Cases | Time/hours | 02:00 | 04:00 | 06:00 | 08:00 | 10:00 | 12:00 | 14:00 | 16:00 | 18:00 | 20:00 | 22:00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outside temperature | 28.52 | 27.46 | 27.46 | 31.73 | 38.14 | 42.59 | 44.9 | 43.83 | 40.63 | 36 | 32.8 |
| Case 02 (30% opening) | Single glazing (single clear 3 mm | 28.64 | 29.62 | 26.29 | 23.24 | 23.24 | 23.23 | 23.23 | 24.07 | 24.83 | 25.32 | 25.38 |
| | | 30.89 | 30.46 | 27.42 | 23.17 | 23.19 | 23.19 | 23.19 | 27.98 | 29.98 | 30.05 | 29.39 |
| Case 03(40% opening) | | 31.13 | 30.6 | 27.51 | 23.18 | 23.21 | 23.21 | 23.21 | 28.39 | 30.56 | 30.65 | 29.71 |
| Case 04 (50% opening) | | 31.35 | 30.72 | 27.59 | 23.19 | 23.22 | 23.22 | 23.22 | 28.8 | 31.24 | 31.2 | 30.11 |
| sizes of the type of glazing30%. | | 31.13 | 30.75 | 30.37 | 23 | 23 | 23 | 23 | 31.94 | 34.06 | 33.73 | 32.88 |
| Case 01 (The original prototype) | Double glazing (double clear 3 mm/13 mm air) | 28.41 | 29.5 | 26.19 | 23.24 | 23.24 | 23.23 | 23.23 | 24.07 | 24.81 | 25.24 | 25.26 |
| | | 30.73 | 30.36 | 27.38 | 23.17 | 23.18 | 23.19 | 23.19 | 27.8 | 29.62 | 29.85 | 29.14 |
| Case 02 (30% opening) | | 30.95 | 30.51 | 27.5 | 23.18 | 23.2 | 23.2 | 23.2 | 28.09 | 30.14 | 30.3 | 29.47 |
| Case 02 (40% opening) | | 31.21 | 30.67 | 27.6 | 23.19 | 23.22 | 23.21 | 23.21 | 28.48 | 30.82 | 30.9 | 29.95 |
| Case 04 (50% opening) | | 26.31 | 25.58 | 24.46 | 23.12 | 23.14 | 23.14 | 23.14 | 23.14 | 26.15 | 27.3 | 26.54 |
| Case 01 (The original prototype) | Dbl LoE (e2=.1) Clr 3mm/13mm Airr | 28.08 | 29.07 | 23.23 | 23.24 | 23.23 | 23.23 | 23.23 | 24.05 | 24.76 | 25.1 | 25.04 |
| Case 02 (30% opening) | | 30.44 | 30.12 | 23.17 | 23.16 | 23.17 | 23.18 | 23.18 | 27.46 | 29.14 | 29.4 | 28.82 |
| Case 03 (40% opening) | | 30.63 | 30.24 | 23.19 | 23.17 | 23.19 | 23.19 | 23.19 | 27.78 | 29.65 | 29.8 | 29.2 |
| Case 04 (50% opening) | | 30.8 | 30.36 | 23.2 | 23.18 | 23.2 | 23.2 | 23.2 | 28.01 | 30.07 | 30.2 | 29.42 |
| sizes of the type of glazing30%. | | 26.2 | 25.52 | 23.13 | 23.12 | 23.13 | 23.13 | 23.14 | 25.93 | 27.02 | 27 | 26.36 |

**Table 2:** Energy Per Total Building Area [kWh/m2]

| Cases | Single glazing (single clear 3 mm) | Double glazing (double clear 3mm+13mm air | Dbl LoE (e2=.1) Clr 3mm/13mm Airr |
|---|---|---|---|
| Case 01 (The original prototype) | 277.63 | 268.91 | 260.4 |
| Case 02 (30% opening) | 289.41 | 280.5 | 264.92 |
| Case 03(40% opening) | 309.07 | 294.3 | 279.28 |
| Case 04 (50% opening | 328.78 | 314.51 | 290.29 |
| Sizes of the type of glazing 30%. | 292.54 | 281.54 | 269.01 |

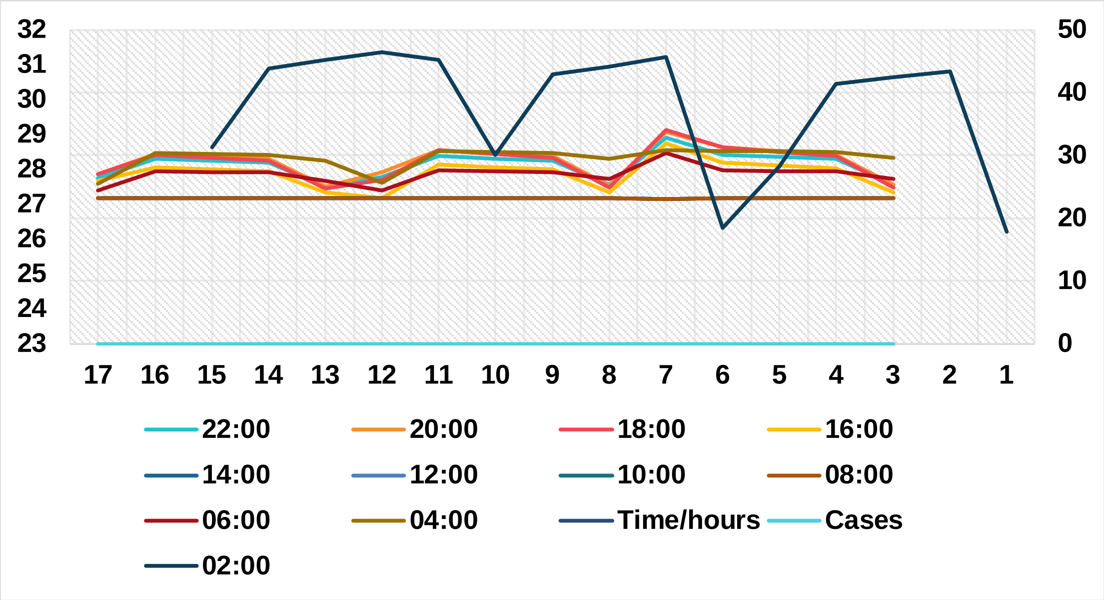


**Figure 6:** Details of the air temperature (°C) for each case study with cooling.

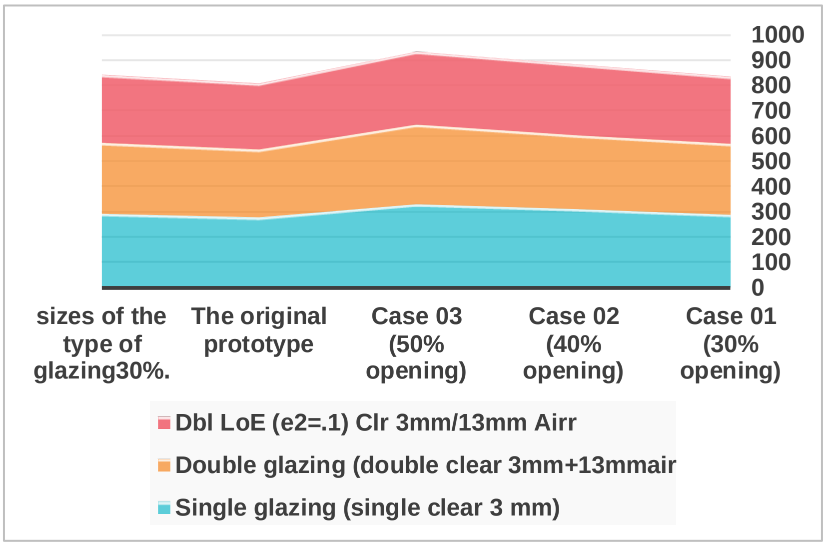


**Figure 7:** Energy consumption for each case study

**Table 3:** The first case of hypothermia after case simulation (30% WWR) with multiple, continuous windows

| Cases | Single glazing (single clear 3 mm) | Double glazing (double clear 3mm+13mm air | Dbl LoE (e2=.1) Clr 3mm/13mm Airr |
|---|---|---|---|
| sizes of the type of glazing 30%. | 292.54 | 281.54 | 264.92 |
| Case 01 (30% opening) | 289.41 | 280.5 | 269.01 |

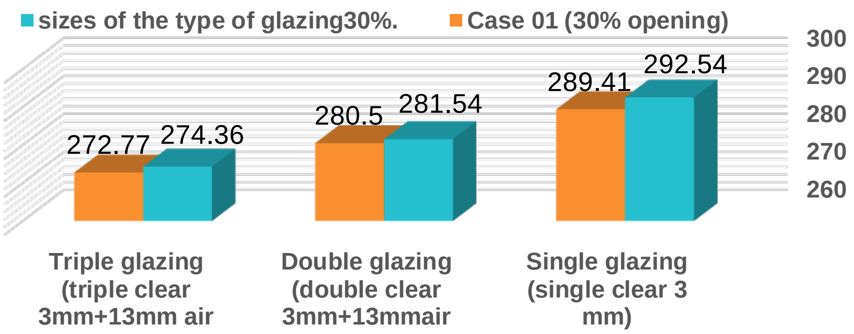


**Figure 8:** The first case of hypothermia after case simulation (30% WWR) with multiple, continuous windows.

The result of the illumination measurement of the existing case with two modifications showed the lowest energy consumption, which achieved the natural comfort lighting of the study space according to (LEED v4 Option 2) standard. The illumination measuring results for these cases with the window dimensions (2.5 * 2) and the height of the session 90 cm (Figure 9) were shown in Table 4. The analysis showed a failure to reach the standard, which only 41.4% illuminated in the case from the total area, with 20.2% reaching the requirements.

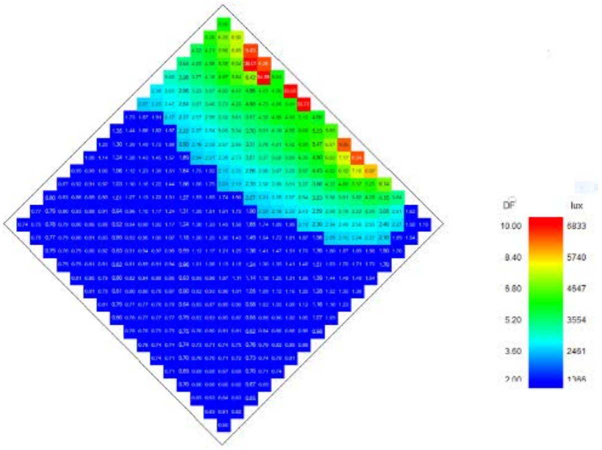

**Figure 9**: The VGA analysis of the existing case according to the "LEED v4 Option 2" standard.

**Table 4**: the summary results of illumination measurement according to the "LEED v4 Option 2" standard.

| Summary Results | | | | |
|---|---|---|---|---|
| Total area ($m^2$) | | | 48.8 | |
| Total area meeting requirements ($m^2$) | | | 20.2 | |
| % Area within illuminance threshold limits | | | 41.4 | |
| LEED V4 Option 2 Credits | | | FAIL | |
| Eligible zones for daylighting, worst-case values for 9:00 and 15:00 | | | | |
| Block | Zone | Floor area ($m^2$) | Min illumination (lux) | The working plane area within Limits (%) |
| ground floor-A | classroom 2 | 48.8 | 311.32 | 41.4 |
| Total | | 48.8 | 311.32 | 41.4 |

Using the glazing ratio of 30% with a continuous window, which is the window dimensions (5.2 * 1.5), the results showed that illumination reached the first step of the standard by reducing energy consumption, see Figure 10 & Table 5.

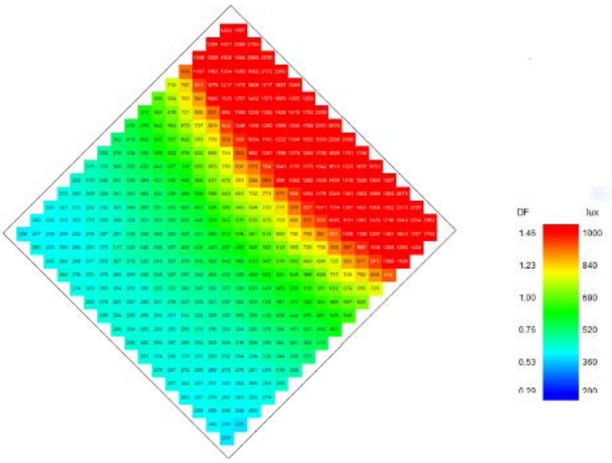

**Figure 10**: results of modification case No.1 with continuous windows type.

**Table 5**: The summary results of case No. one

| Summary Results | | | | |
|---|---|---|---|---|
| Total area ($m^2$) | | | 50.2 | |
| Total area meeting requirements ($m^2$) | | | 39.9 | |
| % Area within illuminance threshold limits | | | 79.4 | |
| LEED V4 Option 2 Credits | | | 1 | |
| Eligible zones for daylighting, worst-case values for 9:00 and 15:00 | | | | |
| Block | Zone | Floor area ($m^2$) | Min illumination (lux) | The working plane area within Limits (%) |
| ground floor-A | classroom 2 | 50.2 | 219.35 | 79.4 |
| Total | | 50.2 | 219.35 | 79.4 |

In the case of glazing also 30%, but with multiple windows (1.5*2) divided into three windows, the results are illustrated in Figure 11 and Table 6. In this case, the required lighting was achieved for the classroom space with dimensions were (7.2 * 7.20m, meaning that it fit the space 1: 1. Accordingly, it is applied to the rest of the cases with proportions (3: 1, 2: 1).

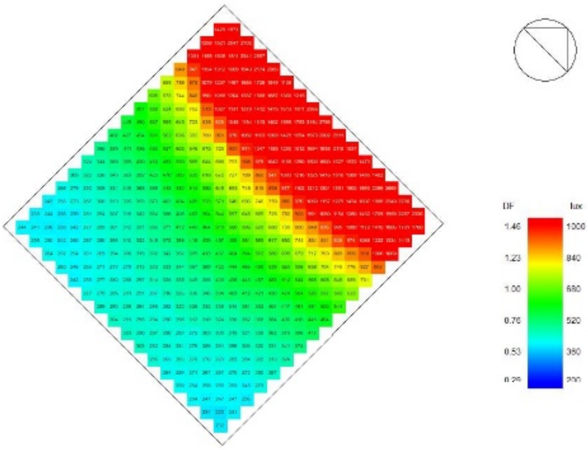

**Figure 11**: The illumination analysis of the modification case no.2.

**Table 6**: Summary results of modification case No.2.

| Summary Results | | | | |
|---|---|---|---|---|
| Total area ($m^2$) | | | 50 2 | |
| Total area meeting requirements ($m^2$) | | | 39.9 | |
| % Area within illuminance threshold limits | | | 78.0 | |
| LEED V4 Option 2 Credits | | | 1 | |
| Eligible zones for daylighting, worst-case values for 9:00 and 15:00 | | | | |
| Block | Zone | Floor area ($m^2$) | Min illumination(lux) | The working plane area within Limits (%) |
| ground floor-A | classroom 2 | 50 2 | 219.35 | 79.4 |
| Total | | 50 2 | 219.35 | 79.4 |

The rate of glazing is the effective factor in achieving the illumination required for the education interior spaces, whether continuous or multiple. Determining the best windows types depends on the users' preferences; most prefer multiple windows cases, which increased energy consumption. Double glazing with thermal radiation isolation with characteristics (SHGC) 0.764, (Light transmission) 0.812 can reduce the side effects of the multiple windows type.

# 6 Conclusion

The efficiency of the natural lighting performance does not decline by determining the area of the windows only. However, selecting the characteristic and variable of the building direction, external shape, plan of its interior spaces, and interior and exterior finishing materials of the glass can contribute to achieving efficient levels of natural lighting in the interior spaces. From this study, vertical rectangular or square shape windows provided better lighting distribution within the space. Moreover, dividing the widow area is the best solution for providing comfortable lighting to the users and achieving an efficient natural lighting level. The effective characteristics of windows in educational buildings in the University of Mosul should be with a glazing ratio of 30% with window dimensions (5.2 m* 1.5m) or (1.5m * 2m) dimensions of the length to width ratio space of 1: 1 to provide adequate lighting and energy-saving at the same time. As it achieves the required illumination according to the LEED standard. The windows' design compatibility with the users' needs in the educational spaces has a major role in the functionality and efficiency of the building. Daylight has the necessary feedback to improve the quality of light inside the space and provide great psychological and physiological effects on the users. In education buildings, users' need adequate lighting connected to the workbench if it is a drawing, laboratory or classroom without any glare or dazzling, which affects the users' psychological and physical needs.

The interior space of the education building is an active factor in reducing energy consumption by using natural resources, such as natural lighting and windows characteristics. The interior space where users practice the daily work as students or lecturers should design following the users' physical needs of the users which Each type of user has essential needs. Comfortable lighting level is one of the needs linked to other values such as temperature and Vision problems. The relationship between the design of the window and users' needs can assist the designers in providing a comfortable environment, especially for an education building. The current study presented the main factors that can make a change in the energy consumption by redesigning the windows using simulation conducted on the mutual effect between the ratio of the glazing (WRW) and the type of glass used on the energy performance of any buildings, where it examined and compared four alternatives. The study concludes the perfect alternative that reduces heat gain and provides a comfortable lighting level while reducing energy consumption: Glazing 30% with continuous window. The glass type (Dbl LoE (e2 = .1) Clr 3mm / 13mm Air) can use to reduce the energy consumption. The ratio of reducing the energy consumption compared with the original setting of the case study is about 10%, which indicates that the windows design details are necessary to consider in the overall design to reduce the energy consumption and provide comfortable lighting levels. However, some solutions reduce the energy consumption by more than 10%, contrary to the users' needs.

# 7 Availability of Data and Material

Data can be made available by contacting the corresponding author.

# 8 Acknowledgment

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