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Visual Comfort for a Healthy Indoor Environment in Design Studios: The Critical Role of the Building's Orientation and Opening Ratio

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Abstract

Daylight is one of the most important sources for enhancing human activity and improving well-being. The building's orientation and opening area in the walls are significant factors in providing daylight. Ensuring a reasonable usage of daylight in design studio rooms at universities is a crucial task for architects during the design process, as it fosters a comfortable environment for users and enhances their functionality and visual health. This paper aims to reach a comprehensive understanding of the role of windows, or opening ratio, and the building's orientation in providing daylight into design studio rooms in universities in Erbil, Iraq. The research method of this study was to select two universities as case studies in the study area. The relationship between the intensity of the natural lighting and the satisfaction of the users has been determined in these rooms by testing the window-to-wall ratio and investigating the effect of the building's orientation on the visual comfort in the rooms. For this purpose, a questionnaire method has been applied to the students who are using these rooms. The results demonstrated that the window ratio with the window side location plays a key role in the development of visual comfort inside the design studios at the universities in Erbil.

Keywords: Day-lighting, window to wall ratio (WWR), Visual Comfort, Building's Orientation.

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1. Introduction

Visual performance through daylight is important in terms of biological, performing, and emotional aspects (Nazzal, 2005). It is estimated that lighting based on grid-electric consumes 19% of total universal electricity production (Waide and Tanishima, 2006). Thus, it is important to find solutions for building interiors that include designing spaces that can easily adapt to employees and technology while conserving resources (Iranfar and Muhy Al-Din, 2021). Sustainable built environments are vital to the overall environment; thus, a successful project involves incorporating sustainability into each phase of the design process, its

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execution, and post-occupancy. The proper lighting design inside the buildings includes giving occupants access to visual comfort controls and outdoor views, daylighting, and designing for minimal heat gain or loss, including centralized energy management units and energy-efficient light systems. The problem is that lighting is an issue rarely addressed in architectural design because lighting is generally seen as an attachment to the design. It appears to be a very specific technical matter, and the decision about it arises in the finalization of the project. Because architects can solve any lighting problem through artificial lighting solutions. In terms of comfort, daylight for the users of inner spaces is important biologically and emotionally and increases their performance, which is very important for architecture students in design studio rooms. In terms of sustainability, the energy consumption in buildings is increasing progressively, which is negatively impacting the environment and global warming. One of the main sources of increased energy consumption in buildings recently is the intensive employment of artificial lighting. The research tries to answer the following questions: 1) What are the existing visual comfort conditions in the design studio rooms at the universities in Erbil? 2) How does daylight respond in studio rooms with WWR and the building's orientation variables? 3) What are the main parameters for improving the lighting conditions in the design studio rooms in Erbil through natural lighting?

The study aims to gain a better understanding of the visual comfort conditions in the design studio rooms of architecture departments in Erbil in order to improve performance in these inner spaces. The main objective of this study is to evaluate the role of an interior designer's commitment to sustainable interior design practices. This objective will be implemented through the following secondary objectives: 1) Identify the wall window ratio (WWR) in the design studio rooms at the departments of architecture in the universities in Erbil; 2) examine the perception of the occupants regarding the daylight, on sunny days and cloudy days, and in terms of their performance of their duties; 3) estimate the impact of the building orientation on the visual comfort based on the existing condition.

2. LITERATURE REVIEW

2.1 Previous studies

Several studies have been analyzed regarding visual comfort based on the WWR factor in several types of buildings in many places in the world. Syed Fadzil et al. (2013a), carrying out the research, analyze the sufficiency of this bylaw on the requirement of natural lighting for rooms and suggest ways in which they can be improved. Two rooms of the Fajar Building at the University Science Malaysia campus were used as case studies. The study concluded that the wall window ratio WWR of 50% and 25% and the corresponding window to the floor area of 35% and 17% for rooms in the Malaysian context have daylight levels exceeding the suggested standards. Another study by Syed Fadzil et al. (2013b) found that glazing in the daytime is undesirable because the larger the glazing area and the higher the WWR, the higher the internal air temperatures will be and the higher the difference between the outside temperature and the inside temperature. The study also found that WWRs of 60% to 40% to 20% come with an average percentage daylight factor (%DF) of 3.7, 2.5, and 1.7, respectively. The WWR of 20% is found to be more than adequate for natural lighting requirements in residential areas, and it could be decreased even more to WWR of 15–10% due to the abundance of natural daylight. In the same context, Nedhal et al. (2016) carried out similar kinds of research. The study found that there is a strong direct relationship between WFR (wall-to-floor ratio) and natural illumination levels (in terms of DF (daylight factor)). In a local context, a WFR of less than 10% was found to provide sufficient daylight levels in typical rooms, whereas a WFR of more than 25% could cause rooms to be over-light.

Ochoa Morales, C.E. et al. (2012) demonstrated in their study that unprotected windows barely meet acceptance criteria, needing additional control devices. Applying various related criteria with adequate values increases the diversity of acceptable solutions, but too many limit it.

Shen, H., and Tzempelikos, A. (2010) used in their research dynamic (variable) view factors for computing inter-reflections between variable surfaces; these metrics are presented as a function of the façade. Parameters (window size, properties, orientation, and geometry). Results are presented for different climatic locations in the US to include the impact of weather conditions. In all locations, daylight "saturation" is observed for window-to-wall ratios higher than 40%.

Vanhoutteghem, L. et al. (2015), in their study, focus on the relationship between size, orientation, and glazing properties of façade windows for different side-lit room geometries in Danish 'nearly zero-energy' houses. The results show that low U-values are needed in both north- and south-oriented rooms before large window areas lead to reductions in space heating demand. Furthermore, we must carefully design windows in south-oriented rooms to prevent overheating. Design options for the prevention of overheating, however, include glazing with solar control coatings, which are therefore obvious alternatives to dynamic solar shadings. Regarding room geometry, deep or narrow south-oriented rooms show difficulties in reaching sufficient daylight levels without overheating.

The previous studies demonstrated several ways to address the issue of visual comfort inside buildings. Many studies have been conducted in tropical areas like Malaysia and the Mediterranean, as well as in areas with temperate climates. Several methods have been applied in order to find the actual level of visual comfort: direct measurement, mathematical calculation, as well as interviews and questionnaires. However, the review demonstrated the lack of these types of studies in the semi-arid climate, which is concerned with Erbil. When the study involves the orientation of the buildings with the WWR factor in Design Studios classes at the Department of Architecture, as in the current study, this can be considered a gap in the literature in this study.

2.2 Building Orientation and Natural Lighting

Givoni (1969) confirmed that the amount of natural lighting received by the building depends on its orientation. In regions where the ambient temperature affects comfort more than ventilation, orientation concerning the sun is important. Hence, the orientation of facades influences the ability of the penetration of solar radiation incidence (Muhy Al-Din et al., 2023; Muhy Al-Din et al., 2024), as seen in Figure '1'. Various sides of the building gain a different level of natural lighting. For instance, the west direction of the building gets direct sun rays in the afternoon, while the east direction gets them in the morning. The southern exterior faces get direct sun radiation incidence throughout the day, especially in the winter when the sun ecliptic is lower. While exterior faces were placed in the north direction, they would get indirect sun radiation (Givoni, 1969). The amounts of sun rays obtained by the building are defined by radiation (Marsh, 2000).

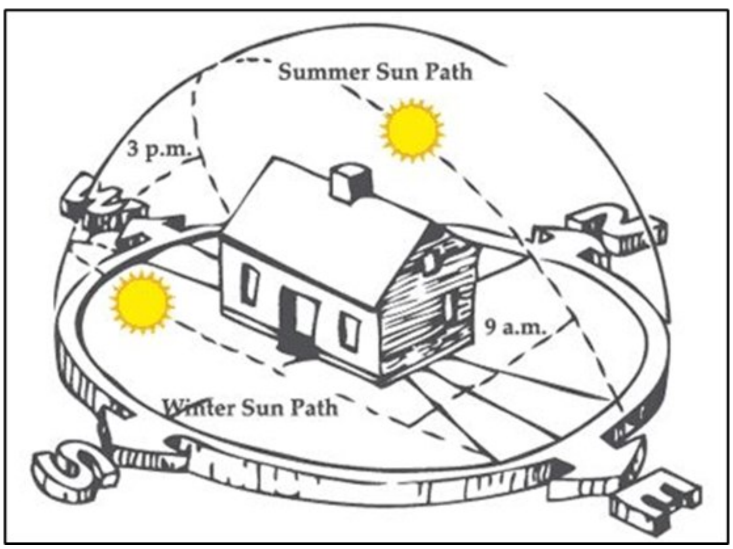

Figure 1. The orientation of the building and its relation to sun ecliptic. (Rozhbayani, 2018).

Selecting the correct building orientation to take advantage of the seasonal sun's motion permitting the natural lighting in winter to get into the building prevents direct penetration in summer. This results in increasing visual comfort and thermal comfort for working spaces to be more habitable through accessibility to the natural heating, cooling, and lighting parameters, consequently reducing energy consumption in the building (Rozhbayani, 2018).

2.3 WWR in Hot and Arid Climate

According to ANSI/ASHRAE (2013), the wall window ratio (WWR) is a ratio commonly used to indicate the area of glazing in a building. A high WWR indicates a large area of glazing or glass used in the exterior wall compared to its non-transparent parts, which can be wood, brick, or concrete. A WWR of 50% indicates similar areas of opaque to transparent parts in the exterior wall. Based on ASHRAE 90.1 (2016), the best WWR for the building is 24%.

Erbil climate can be classified as a hot and arid climate (Saeed, 2012). The solar radiation intensity in a hot and arid climate is high on the east and west sides during the summer and on the south wall in the winter. Thus, more windows should be oriented to the north and south. Simple window shading is easy to facilitate as a result of the high solar altitude and greater reflection of solar radiation from the façade due to the lower angle of incidence. According to research on the climate of the United Arab Emirates, west and east orientations have full illumination, although in terms of thermal effects (St Clair, 2009). However, the east orientation is useful, and the focus should be on west-oriented windows concerning direct solar radiation to prevent overheating; hence, vertical shading devices are recommended (Ouahrani, 2000). The research conducted by Ouahrani (2000) is based on the climate of Ghardaïa, which has a hot and arid climate.

WWR Guidelines criteria for buildings in Saudi Arabia in a hot and arid climate have been designed by Al-Shaalan et al. (2014) for different glazing types based on U-value and SHGC (solar heat gain coefficient), as seen in Table ‘1'.

Table 1. The guidelines of WWR as per the orientation of buildings in a hot and arid climate. (Al-Shaalan et al., 2014)

Glazing Type	U-value [W/m K]	SHGC	Window to Wall Ratio [%]			
			East	West	South	North
6 mm, single, clear	6.08	0.710	< 5	< 3	< 4	< 5
6 mm, single, reflective	6.42	0.342	7	6	8	9
6 mm, double, tinted	3.43	0.370	12	10	9	13
6 mm double, reflective	3.35	0.241	20	17	22	18

3. Methodology

Specific design studio rooms with different orientations in the department of architecture at two buildings, Tishik University, and Salahaddin University, will be selected as case studies. Studying the relationship between the intensity of the natural lighting and the satisfaction of the users will be conducted in these buildings through the size of windows and their proportion to the total area of the walls (WWR). Also, investigate the effect of the building's orientation on the visual comfort of the buildings by obtaining the opinion of the users of these spaces. The analytical study is based on secondary sources (theoretical sources), such as books, research, magazines, and credible online sources. In addition to that, primary sources will be used in the study, such as direct measurement and interviews with the building users, as seen in Figure ‘2'.

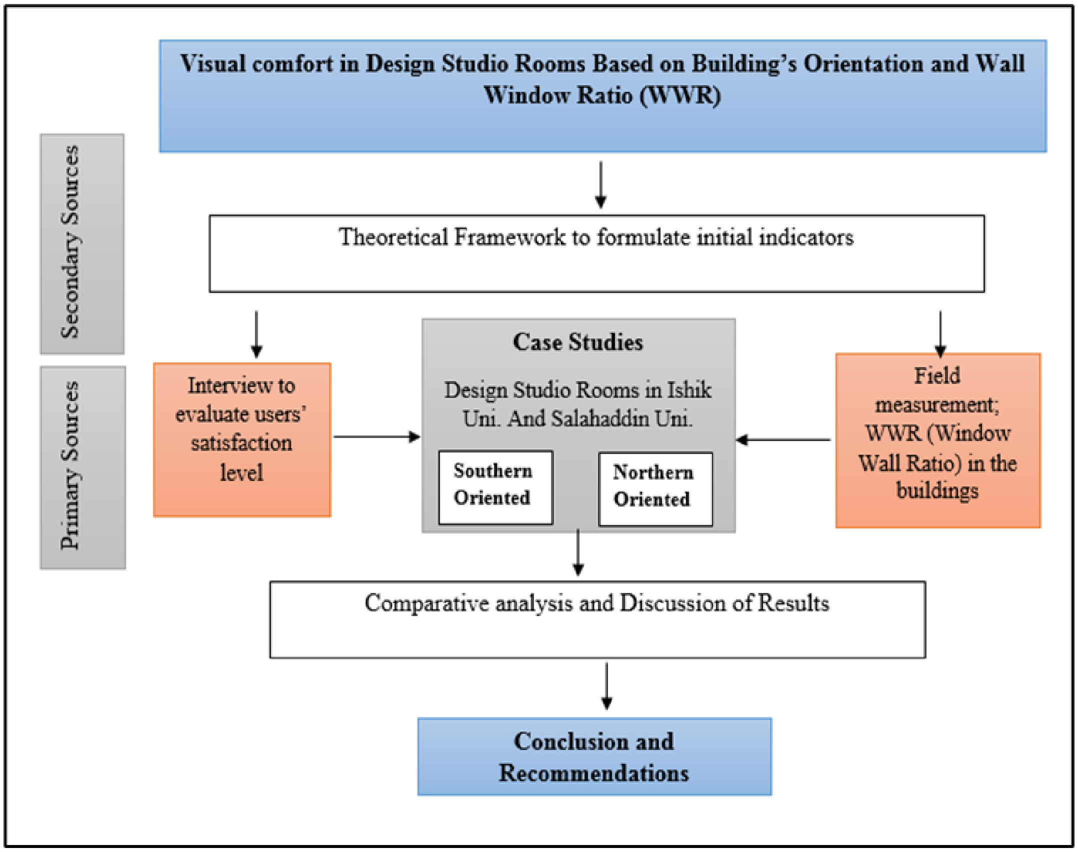

Figure 2. Methodology layout.

3.1 Case Studies

Two design studio rooms (northern-oriented and southern-oriented) have been selected as case studies from two universities in Erbil, namely, Tishik University and Salahaddin University. The purpose is to examine the effect of the natural lighting on visual comfort in these rooms.

3.1.1 Tishik University

Tishik University has been selected as one of the two universities in Erbil. It is located in the south-west of the Erbil citadel, as seen in Figure '3'.

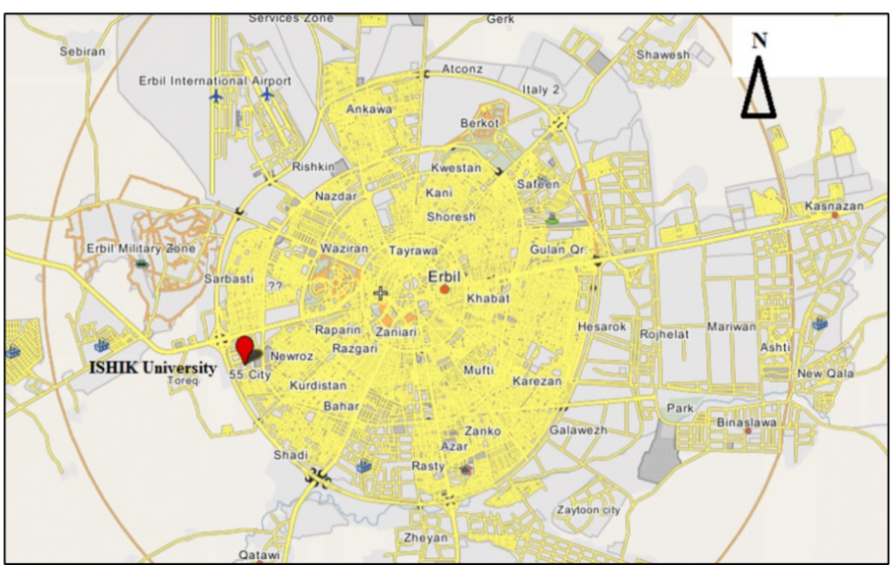

Figure 3. Location of Tishik University in Erbil. Source: UNESCO World Heritage Centre. (2014)

1. Southern- oriented design studio room.

The studio room is located on the southern side of the university on the 5th floor and has a capacity of 45 students. The studio contains five windows on the southern façade, as seen in Figure ‘4’.

Figure 4. Southern Design studio room at Tishik University.

The dimension of this class is 17 m x 6 m, and the total area of the floor is 102 m2. The height of the roof is 3 meters. See Figure ‘5’.

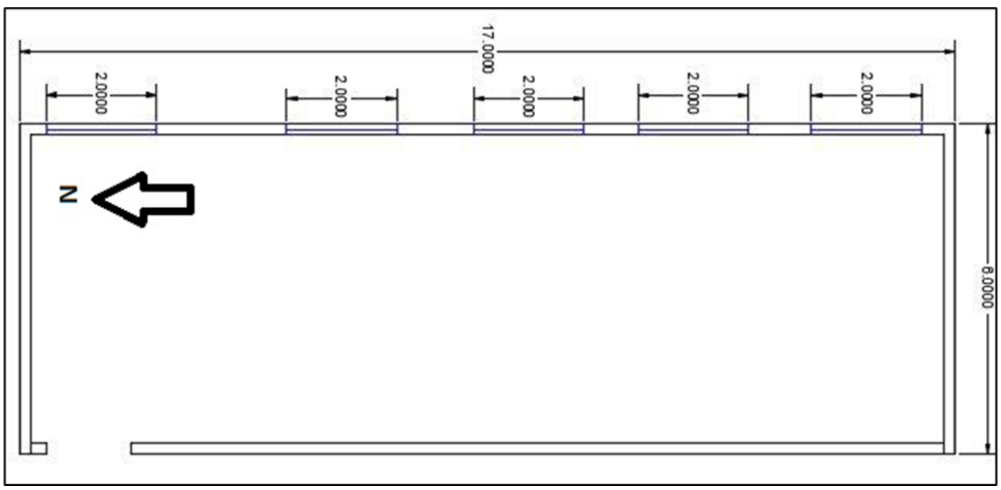

Figure 5. Plan of the Southern Studio class at Tishik University.

The windows are available in the eastern façade of the class; the total window area in the wall is 20 m2, and the area of the wall is 51 m2, thus the WWR (Ration between window area and total wall area) is found to be equal to 39%, as seen in Figure ‘6’.

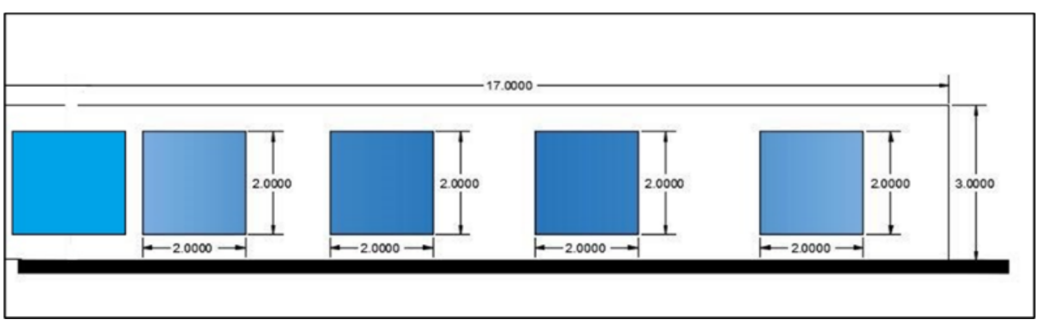

Figure 6. Number and dimension of windows in the southern studio at Tishik University.

2. Northern- oriented design studio room.

The room is located in the northern direction of the university on the 5th floor, with the same capacity and dimensions as the southern studio room. The studio contains four windows on the northern façade, as seen in Figure '7'.

Figure 7. Northern Design studio room at Tishik University.

The dimension of this class is 17 m x 6 m, and the total area of the floor is 102 m2. The height of the roof is 3 meters. See Figure '8'.

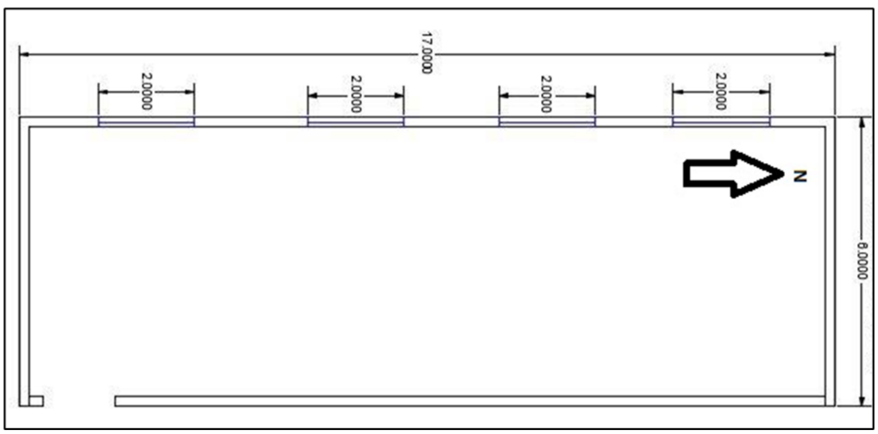

Figure 8. Northern Design studio room at Tishik University.

The windows are available on the northern façade in this class. With the same procedure that was mentioned in the southern-oriented studio, the total area of the windows was 16 m2, whereas the area of the walls was 51 m2. Therefore, WWR was found to be equal to 31%, the same as in the southern studio, as seen in Figure '9'.

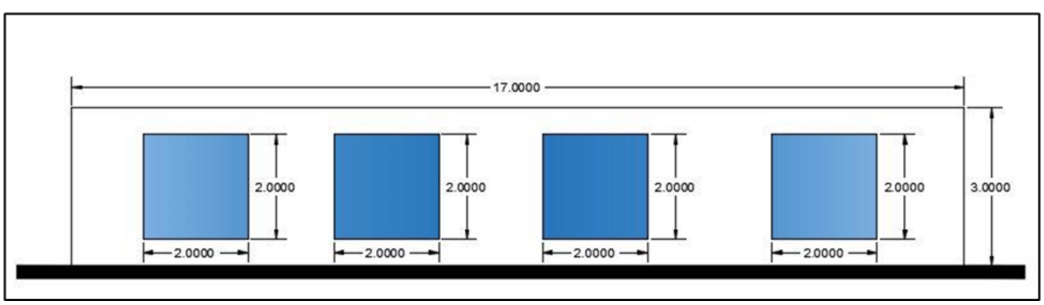

Figure 9. Number and dimension of windows in the Northern Studio at Tishik University.

3.1.2 Salahaddin University
Salahaddin University has been selected as another university in Erbil. It is located in the south of the Erbil citadel, as seen in Figure '10'.

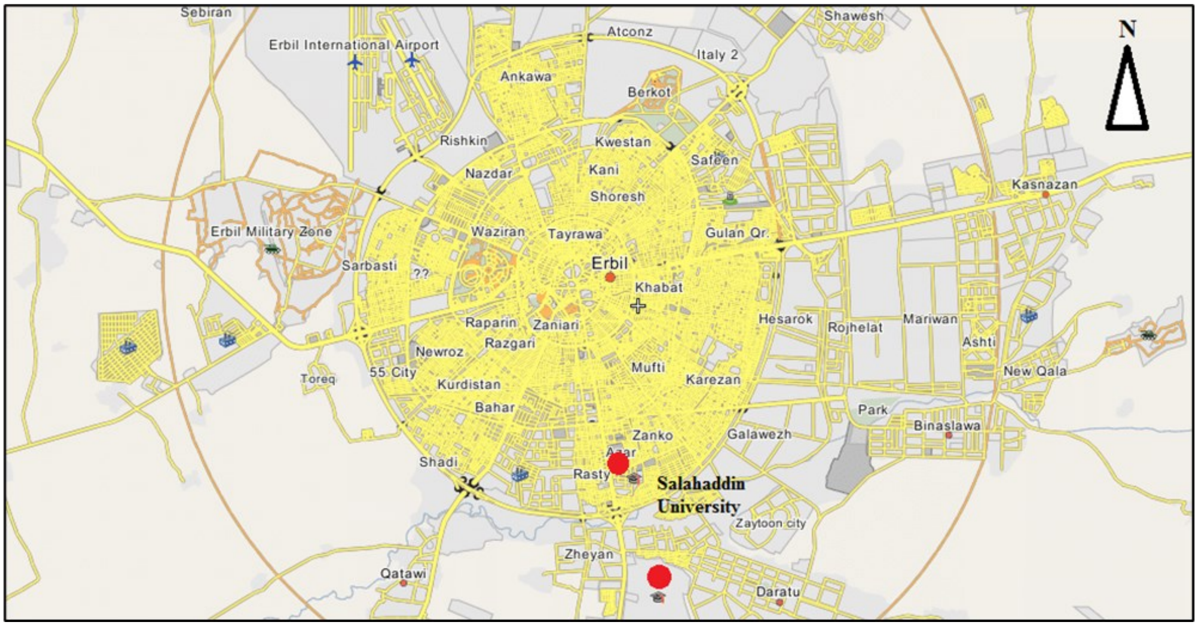

Figure 10. Location of Salahaddin University. Source: UNESCO World Heritage Centre. (2014)

1. Southern- oriented design studio room.

The studio room at Salahaddin University, which is located on the southern side of the 1st floor, has a capacity of 35 students. The studio contains four windows on the eastern façade, as seen in Figure '11'.

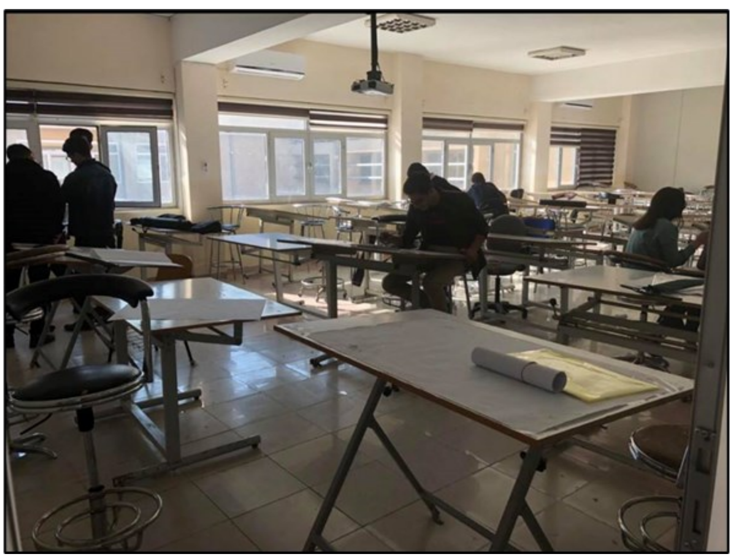

Figure 11. Southern Design studio room at Salahaddin University.

The dimension of this class is 14.4 m x 7.2 m, and the total area of the floor is 103.7 m2. The height of the roof is 3 meters. See Figure '12'.

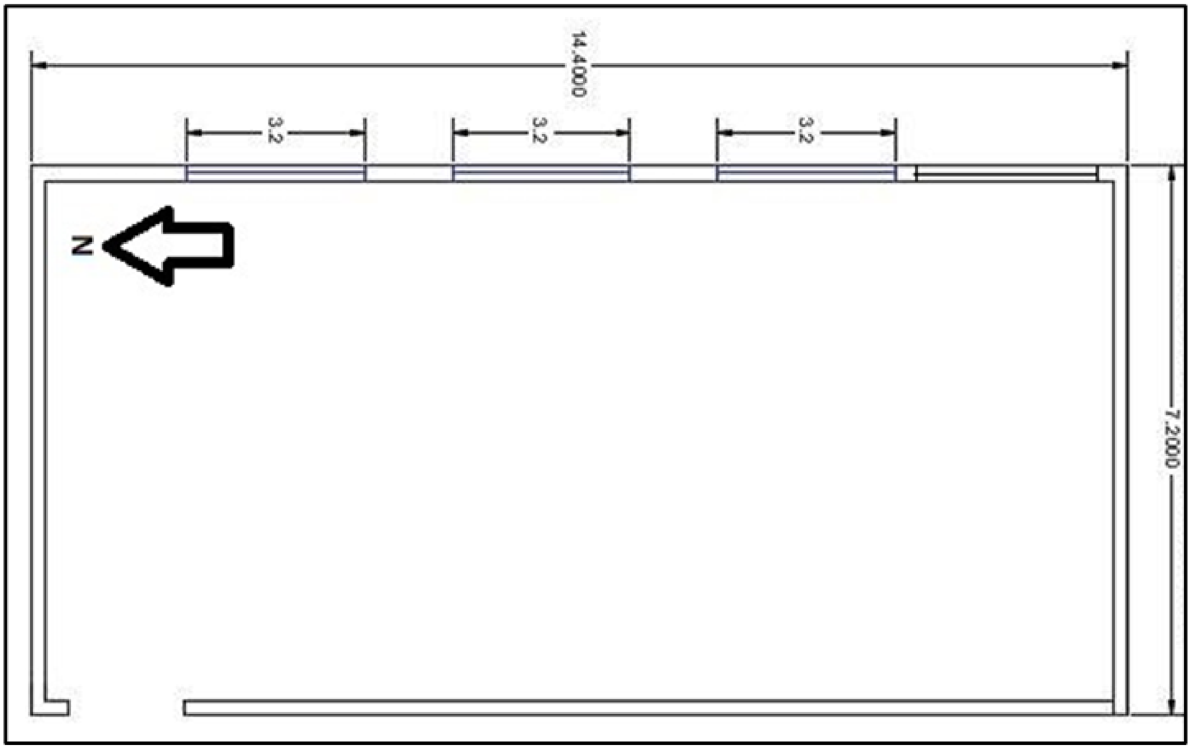

Figure 12. Southern Studio class plan at Salahaddin University.

The studio contains four windows on the eastern façade; the total area of the wall is 43.2 m2, and the total window area is 17.92 m2. The WWR in this room is 41.5%, as seen in Figure '13'.

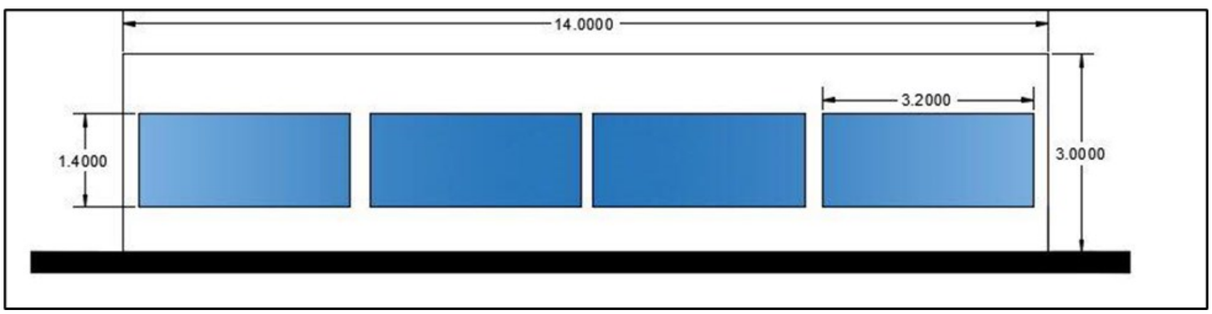

Figure 13. Number and dimension of windows in the southern studio at Salahaddin University.

2. Northern- oriented design studio room.

This room is located on the northern side of the University of Salahaddin on the 1st floor, with the same capacity and dimensions as the southern studio room. See Figure '14'.

Figure 14. Northern Design studio room at Salahaddin University.

The dimension of this class is 14.0 x 10.0 m, and the total area of the floor is 140.00 m2. The height of the roof is 3 meters. See Figure ‘15’.

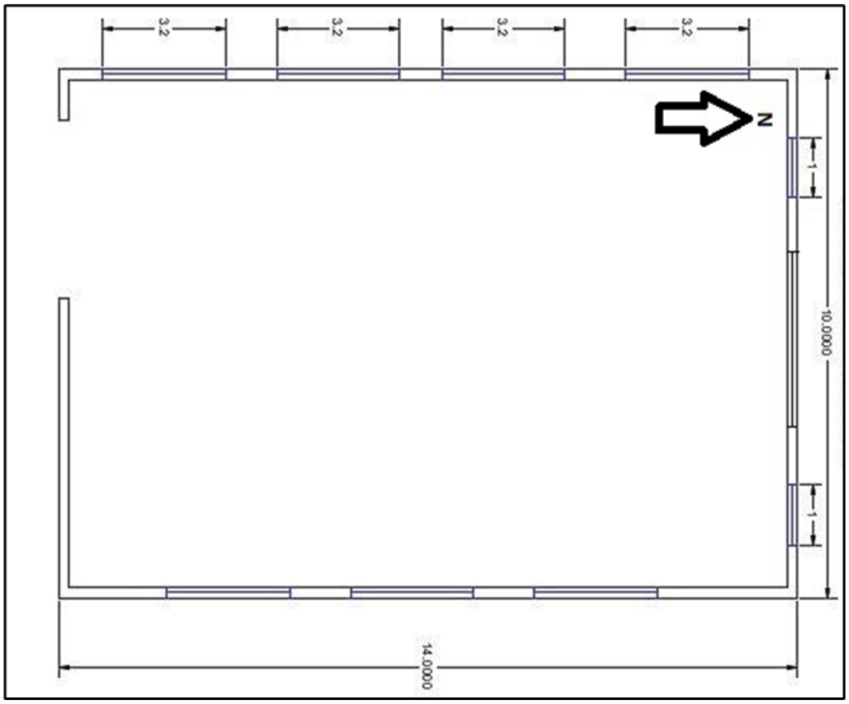

Figure 15. Northern Studio plan at Salahaddin University.

The studio contains four windows on the western façade, three windows on the eastern façade, and three windows on the northern façade. See figure ‘16’. The total area of the external walls in this studio is 114 m2, while the total area of the windows is 38.64 m2. Therefore, the WWR in this studio is equal to 35%.

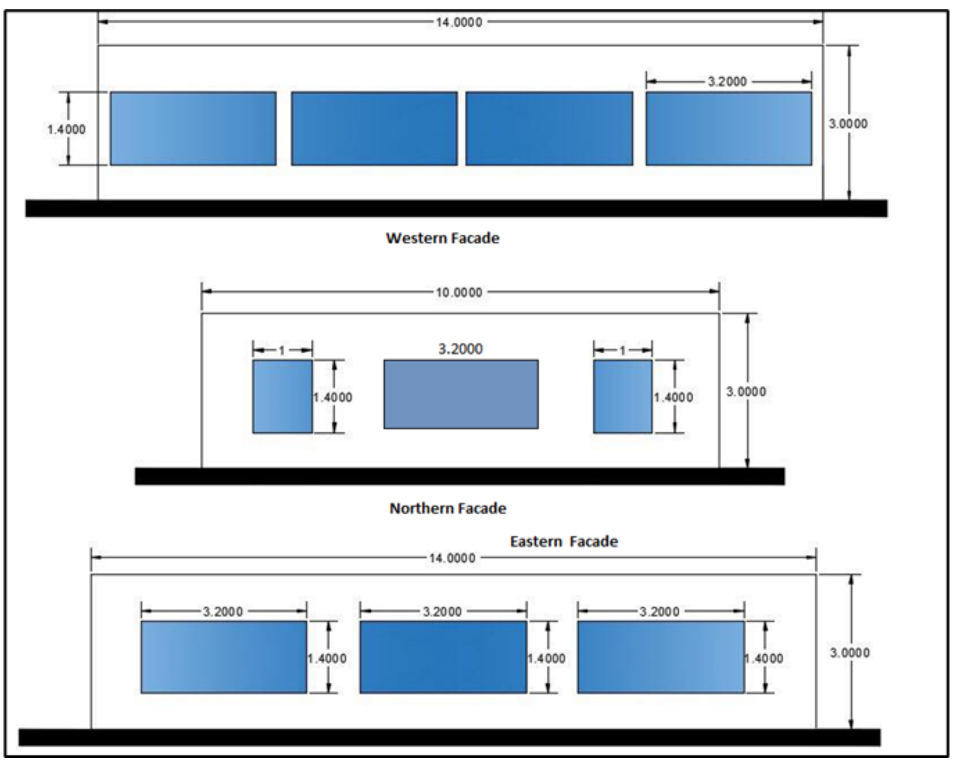

Figure 16. Number and dimension of windows in the Northern Studio at Salahaddin University.

3.2 Questionnaire

The questionnaire was conducted with 30 students using both design studio rooms (northern and southern) at Tishik University, and with the same procedure, 30 students using northern and southern design studio rooms at Salahaddin University were asked through the questionnaire about their visual comfort in the studio rooms. The last question was asked to the students in order to see if they had any problems with their eyes, which could affect their answers. See Figure 17.

Questionnaire

1. Name: ....

2. Stage: a. 3rd year....... b. 4th year....... c. 5th year.......

3. Name of University: …………………………

4. Orientation of the Studio Room: a. Southern [….]; b. Northern [….]

5. Age of the Participant...

6. Evaluate your visual comfort feeling with daylight during the design in studio rooms, without using artificial lighting on;

a. Sunny days
1. Good [….]; 2. Average [….]; 3. Bad [….].

b. Cloudy days
1. Good [….]; 2. Average [….]; 3. Bad [….].

7. Are you using artificial lighting or natural lighting during the class?

a. Artificial [….]; b. Natural [….].

8. Do you prefer artificial light or natural light during your work in studio room?

a. Natural Light [….]; b. Artificial Light [….]

9. In general, how you evaluate the visual comfort inside the studio with the help of artificial lighting?

1. Good [….]; 2. Average [….]; 3. Bad [….].

10. Do you have any disease in your eyes?

a. Yes [….]; b. No [….].

Figure 17. Sample of the questionnaire form.

4. Finding and Discussion

Based on the obtained data from measurement and the observations of the northern and southern design studios at Tishik University and Salahaddin University for calculating WWR in each studio, the findings demonstrated that in Tishik University, both southern and northern classes have WWRs equal to 39%, while the northern classes have WWRs of 31%. While for Salahaddin University, the southern rooms are shown in Table ‘2’.

Table 2. WWR for the southern and northern design studios in Tishik and Salahaddin Universities.

University	studio Orientation	WWR
Tishik University	Southern	39%
	Northern	31%
Salahaddin University	Southern	41.5%
	Northern	35%

The questionnaire was conducted with 5th or final-year architecture students in both universities, and the age of participants was between 21- and 24 years. Some of the results of the questionnaire are demonstrated in Table ‘3’, as follows:

Table 2. The answers of the participants regarding a part of the questionnaire.

	University	Good	Aver.	Bad	University	Good	Aver.	Bad
Q3	Tishik				Salahaddin			
Q4	Southern orientation							
Q6	Evaluate your visual comfort feeling with daylight during the design in studio rooms, without using artificial lighting on;							
a	Sunny days?	27%	50%	23%		27%	47%	26%
b	Cloudy days?	23%	37%	40%		23%	40%	37%
Q10	In general, how you evaluate the visual comfort inside the studio with the help of artificial lighting?	83%	17%	0%		87%	13%	0%
Q4	Northern orientation							
Q6	Evaluate your visual comfort feeling with daylight during the design in studio rooms, without using artificial lighting on;							
a	Sunny days?	17%	23%	50%		07%	6%	87%
b	Cloudy days?	17%	17%	67%		27%	30%	43%
Q10	In general, how you evaluate the visual comfort inside the studio with the help of artificial lighting?	83%	17%	0%		73%	27%	0%

The results demonstrated that almost half of the students in the southern studio at Tishik University and Salahaddin University with WWR (39% and 41.5%), respectively, evaluated natural lighting by (average), while a quarter of them evaluated it by (bad), and another quarter evaluated it by (good). The reason is that both studio rooms have windows on the eastern side, which allow sunlight to enter the building from the morning until noon. This will let the students who are near the windows feel more discomfort visually because of direct sun ray incidence, and those who are in the middle of the room feel good visual comfort, while those who are far from the windows feel average visual comfort. On the other side, on cloudy days, the number of students who are feeling good visual comfort is less, and the number of students the number of students who are feeling bad is more, and the number of students who feel average visual comfort is also less than on a sunny day. The reason is that less 'lux' or low natural lighting penetrates the studio.

The northern-oriented studio with WWR (31%) on sunny days at Tishik University demonstrated that they feel lower visual comfort than the southern side, where 67% of the students evaluated the visual comfort by Bad. This is because the windows are laid on the western side, which is not getting proper lighting during the morning and noon hours, which are the working hours. Consequently, on cloudy days, the visual comfort is worse because there is less lighting penetration inside the studio. Regarding Salahaddin University, in the northern-oriented studio that has WWR (35%), the visual comfort condition is relatively the same, and 87% of the students feel bad visual comfort on sunny days. The reason is that the three sides of the studio room have windows (north, east, and west), which creates a glare and visual discomfort inside the studio because the source of lighting is from three sides. However, during cloudy days, the visual comfort is better in this studio because the glare is less because the DF (daylight factor) is changing. Hence, only 43% of the students evaluated visual comfort as bad. Furthermore, the questionnaire demonstrated that the students prefer natural lighting more than artificial lighting systems in their design studio, where 73% of the students preferred natural lighting inside the studio. On the side, the questionnaire showed that the majority of the time the students use artificial lighting systems, where 97% of the students use artificial lighting at Tishik University, and 93% of the student always use artificial lighting.

5. Conclusion

Under the influence of daylight, humans started to develop their senses, which was the first source that humans utilized since their emergence on Earth. Thus, it is common to experience daylight spontaneously as 'Natural' and feel visual comfort with experiencing this source. The study concluded that the relationship between WWR and the orientation of the window side plays a very effective role in the visual comfort inside design studio rooms. Commonly, the study examined that with the mentioned WWR for both universities, the southern studio rooms with eastern side windows are located in the rooms. The results demonstrated that visual comfort increases on sunny days and decreases on cloudy (sky-overcast) days because the DF (daylight factor) is changing. However, with the mentioned WWR for the northern studio rooms and the western window side location in the studio room at Tishik University, the visual comfort was lower than in a southern studio. The reason is not WWR percentage alone, but because of the location of the windows, which were on the western side. The eastern side allows sun-ray incidence from the morning until the afternoon, which is the main time for studying, while the western side allows sun-ray incidence in the afternoon. Furthermore, the northern studio at Salahaddin University demonstrated lower visual comfort compared with the southern studio. The reason is also the location of the windows, but in this case, because of having windows in three directions instead of one proper direction, causes glare and visual confusion for the students. Hence, it demonstrated the worst studio on sunny days, while WWR was 35%, although it demonstrated less discomfort visually on a cloudy day because of low daylight intensity. The paper also concluded that the WWR is important, but it should be compatible with the direction of the windows in the design studio. Where the location of windows on the east side of the rooms is better than on the western side and better than locating the windows on more than one side of the room, regardless of the location of the building on the northern or southern sides, Also, WWR of 35% to 40% is better on sunny days than on cloudy days. In the climatic characteristics of Erbil, the cloudy days are much less than the sunny days; hence, the focus should be on sunny days more. The orientation of the buildings is not effective in terms of visual comfort, but the side of the window location is rather important. Because the sunny days in the climate of Erbil are more than cloudy days, locating the windows in design studio rooms on the eastern side is more functional for using daylight. Although the students prefer natural lighting, the study showed that commonly, the students are using artificial lighting in the studio rooms in both universities, which indicates that the students are generally not satisfied with the natural lighting system inside the design studio.

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Conflicts of interest

The Author(s) declares(s) that there is no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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