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Evaluating the Impacts of Courtyards on Educational Buildings, Case Study in the University of Sharjah

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Abstract: Courtyards are traditionally associated with the Middle East countries, where climate and culture have given shape to a particular type of traditional architecture. The study evaluates the environmental and social impacts of courtyards in an educational building integrated with occupant's interaction behavior. The case study of the University of Sharjah includes eight different courtyards unoccupied for many years, in different locations around the building with various proportions; the objectives were to examine and evaluate the impact of redesigning the interior spaces of the courtyards in terms of environmental and social aspects. The inductive and experimental approach were adopted in this research, where two surveys were conducted for the occupants, before and after the design applications. In addition to the use of eco-tech software for simulation. In conclusion, the results of surveys and interviews clarified the problem and offered some recommendations and simulation analysis provided recommendations and guidelines for designers.

Keywords: courtyards; social sustainability; occupants' behavior; social impacts

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1. Introduction

Each country or region has a unique way of designing buildings to achieve a comfort zone suitable for its population, whether from social or environmental aspects or even economic ones. The courtyard is one of those common elements found in the Middle East region in commercial and residential buildings. However, the courtyard is not a new typology used in buildings but has been around since the beginning of humankind and has been used passively and socially to achieve human comfort.

Courtyard buildings are common in hot arid climate zones, especially in Middle Eastern countries. Over decades, courtyards have changed from being a traditional element in houses to a passively designed strategy implemented in traditional architecture to moderate climate conditions.

The courtyards are built to adjust the climate of the atmosphere and guide natural ventilation into the buildings [1]. Al Masri [2] stated that central courtyards could bring significant cooling effects for houses and other benefits for human dwellings such as privacy and security. However, some research has described courtyards as 'microclimate modifiers' and a 'microclimate regulator', as mentioned in [3–37]. For example, Al-Mumin [4] recommended the implementation of courtyards in hot climates due to the high temperature and harsh thermal environment. In the simulations by Subhashini and Thiagarajar, it is shown that courtyards effectively circulate cooler air into surrounding spaces while promoting cross ventilation [33].

Soflaei et al. [5] aimed to design a courtyard model to improve thermal comfort in traditional courtyard houses in Iran's hot, arid climate. The results showed that square-shaped courtyards performed better than rectangular courtyards. Additionally, increasing

the heights of the courtyards could improve the shading performance and consequently lower temperatures. Similarly, Muhaisen [6] studied the effect of heights at different climate conditions. The study showed that taller walls should surround courtyards in a hot climate, and lower surrounding walls should perform better in winter or cold climates.

Ahmed [7], in his master thesis, pointed out that with the help of vegetation and water ponds and fountains, the ventilation of courtyards will be improved. Similarly, Wei et al. [8] determined that the use of vegetation in courtyards would lower the temperature by 8 °C while rooftop courtyards lowered the temperature by 4.3 °C [27].

Therefore, Ghaffarianhoseini et al. [9] argued that unshaded courtyards could also provide thermally comfortable outdoor spaces only if well-designed courtyards were constructed.

In several research projects, environmental and psychological factors have been considered in evaluating the satisfaction and perception of occupants in different buildings. Different building types such as offices, residential areas, public buildings, and healthcare facilities are studied to find out if visual quality, thermal comfort, noise level, and air quality (i.e., environmental factors) are favorable or not to occupants. In terms of comfort, good visual and acoustic conditions, good air quality, and thermal comfort are all factors that may contribute to a positive environment [34,35].

Courtyards could also induce positive effects on our social and working life if surrounded by arcades and colonnades, paved, landscaped with water bodies, various plants, shade, and light [10]. Almhafdy et al. [11] stated that courtyard buildings could be utilized as appropriate places for promoting healing environments. Therefore, their study results revealed the creative manipulation of courtyards in Malaysian hospital buildings to heal patients. Similarly, Toone [12] determined the impact of garden courtyards on stress levels, and the results showed that participants experienced a lower stress level when sitting in the garden courtyard.

As one of the main vernacular architectural solutions to cope with Iran's hot and dry climate, Ahmadreza Foruzanmehr mentions courtyards as passive design devices in his book *Thermal Comfort in Hot Dry Climates* [30].

It is possible to understand changes that can create convection by examining the cooling system used in a courtyard house. After sunset, the temperature in hot, dry zones drops dramatically because of the reradiation from the sky to the ground. Heat or infrared radiation cannot be reflected back by water vapor into the ground, as occurs in hot moist climates.

Through utilizing the courtyard concept, this phenomenon has been used in the architectural design of houses in order to enhance thermal comfort.

These zones, particularly in the deserts, are hostile to life at ground level. It was common for people to close the outside of their houses and open them upwards into internal courtyards called sahn, which were open to the sky. As a result of this arrangement, temperatures drop by 10–20 °C (18–36 °F) at night. As a symbol of the night sky, the crescent moon could possibly explain the significance of the crescent moon to Arab people and ultimately to all Muslims, even appearing on the flags of eight predominantly Muslim countries [31].

Courtyards in houses act as an outdoor room. They can be used as an extension of the living room where guests are welcomed. In addition, courtyard houses are a safe place for children to play and a private place for women to perform activities and exercise [13].

Traditional architecture results from humans adjusting to the place they live in and how they utilize the available resources to create a comfortable built environment. The United Arab Emirates has hot and humid climatic conditions, and through the studies and documentations conducted on the traditional buildings all over the Emirates, it was noticed that humans developed appropriate solutions to overcome these climatic conditions.

The UAE climate has an apparent effect on the buildings' design, where courtyards are present in most of their buildings (Figure 1). Therefore, courtyards are found in houses, schools, mosques, and even governmental buildings. The implementation of courtyards

became part of the UAE's culture and has affected social aspects, too. Therefore, using the courtyards adds value to buildings in terms of providing environmental and social solutions that create the building's identity in the UAE [16].

(**a**) (**b**) (**c**)

Figure 1. The courtyard house in Sharjah: (**a**) Traditional old courtyard house in Sharjah; (**b**) Inner view for the courtyard house; (**c**) Urban formed courtyard between several houses.

2. Courtyard as a Climate Responsive Design Strategy in UAE

One of the main factors affecting design solutions is Climate Condition when it comes to constructing new buildings, as well as the building's location and function. The hot arid climate of the Middle East was one of the driving forces in adopting courtyards into traditional architecture [17]. Courtyards can temper the indoor environment by improving the natural ventilation and level of humidity, especially with the hot and humid weather coupled with the high temperature in the UAE.

Architecturally, it is possible to lower the indoor air temperature by controlling the indoor airflow rate and using natural ventilation as a passive design method. Having courtyards in buildings was and still is very common application used for ventilation in UAE [18].

In this desert region with less than 10 cm of rainfall per year, the courtyard was used to collect water from the rain, which helped cool the air [19]. The buildings were oriented in a way to allow for maximum daylight coming in. The rooms were placed around the courtyard for the sun to penetrate, but at the same time, the builders made sure that the occupants got the benefits of the sunlight and not being exposed to the harmful effects of the sun, especially during summer where the sun is directly overhead [20].

Courtyards located in residential buildings are exposed to the elements from two fronts, the exterior walls to the outer streets and the courtyard walls to the center, called the "Sahn". Most heat transfer occurs at the latter, mainly due to large and numerous openings in them [21]. Inward-looking designs manage to control the climate of the interior by considering a few factors. These factors include building materials, air movement, solar radiation, humidity level, etc. [28,29].

The choice of insulating materials (e.g., stone) as building blocks offers thermal protection to the interior. Outer walls were often built thicker than interior walls to add to the building's thermal inertia. The overwhelming choice of white as a paint color is understandable as it reflects solar radiation. Courtyards are often located in the northern direction in order to catch the favorable wind [22].

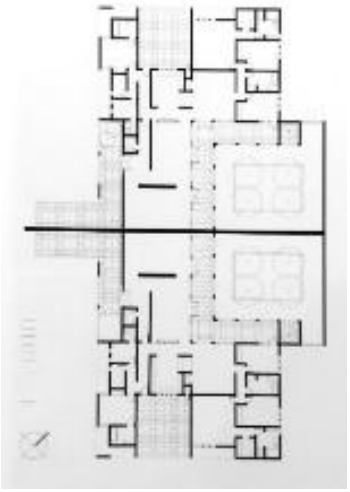
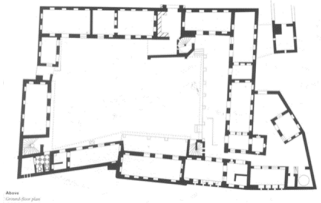
Heat is transferred using a convection process where the air keeps circulating in the courtyard. The cycle begins at night, where the cool air fills the courtyard and the rooms, and thus the walls and floors stay cool till the next day. During mid-day, the sun shines in the courtyard, where it heats the air, and it starts rising to cause the air to circulate [24].

Courtyards Applications in Sharjah, UAE

Of the many buildings in the UAE with courtyards that could have served as case studies, three buildings with different functions were chosen in Sharjah: (1) the Dean's Housing at the American University of Sharjah (AUS), located near to the College of Fine Arts and Design (CFAD); (2) the Calligraphy Square at the Sharjah Calligraphy Museum,

located at the heart of Sharjah; and (3) Bayt Al Nabudah, one of the largest historic houses in the heart of Sharjah. The main reason behind choosing these three buildings is to clarify the role of the courtyard in Emirate buildings even when it has had different functions. Each courtyard's design building features are stated in Table 1.

Table 1. Courtyards applications in Sharjah.

Name	Description	Drawing (Plan)
The Dean's housing at the American University of Sharjah (AUS) 	A 11 × 14 m courtyard positioned north–east and surrounded by a 3 m high wall. The design features are: 1. Creation of a small microclimate to be enjoyed during summer months; 2. Growth of vegetation to add humidity to the air; 3. Non-reflective floors to avoid glare and heat reflection; 4. Glazed façade to avoid glare and heat reflection; 5. Clerestory windows for better lightning level.	
 Calligraphy Square at the Sharjah Calligraphy Museum	A 20 × 50 m courtyard that preserves the traditional urban planning. The design features are: 1. Light-colored mud walls to preserve heat; 2. Location of bench lines in shaded areas.	
Bayt Al Nabudah/ house of Nabudah 	An important meeting place for family and reception space for guests. The design features are: 1. Utilization of clay to preserve heat; 2. An L-shaped main entrance and separate back doors away from the street to ensure high level of privacy; 3. Location of large seating areas in a shaded platform for social gatherings; 4. Growth of vegetation to add humidity to the air.	

This section discusses the parameters that were measured in order to indicate the environmental and social performance of the eight courtyards located in the College of Fine and Arts (CFAD) at the University of Sharjah (UOS).

3. Case Study: The College of Fine Arts and Design

The college of Fine Arts and Design is 1 of the 14 colleges at the University of Sharjah. Therefore, the CFAD society decided to have a closer look at their locked courtyards and try to enhance their performance. Redesigning the courtyards will activate environmental and social aspects to raise the awareness of sustainability among university students [26].

3.1. Climate in Sharjah, UAE

Sharjah is one of the seven emirates of the United Arab Emirates (UAE). It shares boarders with Dubai to the south, Ajman and Umm Al Quwain to the north, and Ras Al Khaimah to the east [27]. According to the Köppen climate classification, Sharjah has a hot desert/arid climate, with warm winters and extremely hot and humid summers. The hottest months are July and August with average temperatures of 42.2 °C and 41.7 °C. The coldest months are January and February with average temperatures of 24.2 °C and 25.2 °C.

The perceived humidity in Sharjah varies greatly depending on the season. Between 18 April and 20 November, 7.1 months of the year are muggier, oppressive, or miserable, and 22% of those days are muggy, oppressive, or miserable. Sharjah experiences 26.4 muggy or worse days per month in August. Sharjah experiences 0.6 muggy days or more in January, when there are fewer than two per month [32].

There is a mild seasonal variation in the average hourly wind speed in Sharjah throughout the year. From 30 December to 7 June, during the windier part of the year, average wind speeds exceed 8.0 miles per hour for 5.2 months. Wind speeds in Sharjah average 9.1 miles per hour during March, making it the most windy month of the year. From 7 June to 30 December, 6.7 months mark a calmer time of year. A 7.8 mile per hour average wind speed is forecast for October in Sharjah, making it the calmest month of the year [32].

On average, the amount of shortwave solar energy incident daily varies greatly from season to season. During the brighter period of the year, which lasts for 2.5 months, there are about 7.2 kWh of incident shortwave energy per square meter on average per day. Sharjah experiences an average daily solar output of 7.8 kWh in June, the brightest month of the year. The darkest part of the year lasts for 2.8 months, from 11 November to 5 February, with an average daily shortwave energy per square meter below 4.9 kWh; 4.1 kWh is the average amount of energy used in Sharjah in December [32].

3.2. Courtyards at the College of Fine Arts and Design (CFAD)

The University of Sharjah is located on the southern edge of Sharjah. The College of Fine and Arts (CFAD) contains eight courtyards, where each is surrounded by one of the departments. Figure 2 indicates the location of each courtyard; the first courtyard is located in the main entrance of the college, where the students' center is close by.

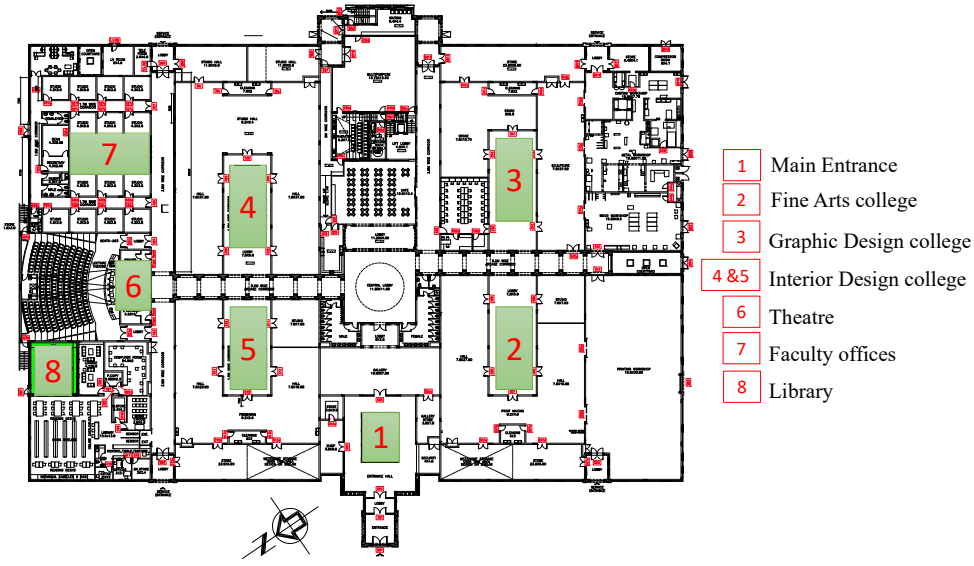


Figure 2. The architectural plan of CFAD highlighting the eight courtyards.

Courtyards 2 and 3 are located near the fine arts and graphic design departments where the courtyards' presences are important sources of sunlight when visiting the studios. Courtyards 3 and 4 are located near the graphic and interior design departments.

Courtyards 7 and 8 are located near the faculty member offices and the library. This study will only consider Courtyards 1, 2, 3, and 4 due to their frequent utilization, and courtyards 5, 6, and 7 were excluded from the analysis due to their limited use.

3.3. Case Study Assessments Parameters

It has traditionally been thought of as a separate element of the design process to conduct an energy simulation and an architectural design. An energy model is similar to an architectural model, except it contains thermal areas instead of elements. Studies have examined how energy simulation has been used by a broad range of users, such as architects, and concluded that technology could be used to make a wider range of decisions [36,37].

As Meir et al. [3] stated, the main function of the courtyard is to improve the human comfort and afford more spaces for different social activities. Consequently, all aspects that might affect the human comfort should be taken into consideration. This study focuses on monitoring the performance of courtyards for the environmental and social aspect.

Generally, sun–shadow relation, ventilation, humidity level, wall surface temperatures, and indoor air temperatures are all factors that can affect the performance of the courtyard [3]. This study will focus on two parameters only (sun–shadow relation, humidity level) and finally compare the average temperature with Sharjah's average temperature at the same months of the year to enhance the courtyard performance and make it more liveable and comfortable for users.

In order to determine the sun–shadow relation, data were collected in two different periods (i.e., Summer/June and Winter/January) using the TR-74Ui Illuminance UV Recorder device (Figure 3). Next, a three-dimensional simulation models were created for the first four courtyards regarding the sun and shadow relation by using Ecotect software. This allowed us to establish the extremes of the sun's movements through the academic year. The shadows were tracked in three different timings: start of classes (8–10 a.m.), start of lunch break (1–2 p.m.), and end of classes (4–5 p.m.).

Figure 3. TR-74Ui Illuminance UV Recorder device.

Because all courtyards had similar average temperatures throughout the day in June and January, the collected data for each courtyard were summed up and averaged. Sharjah's temperature was obtained from Sharjah's climate [28]. This piece of the data will allow us to determine to what extent temperature can affect the social performance of courtyards.

4. Case Study Monitoring

4.1. Case Study Assessments Parameters

4.1.1. Sun–Shadow Relation

The results of the three-dimensional simulation models and accompanying photographs that were taken to track shadow movements are attached in the Tables 2–4.

Table 2. The 3D simulation models for Courtyards 1 and 2.

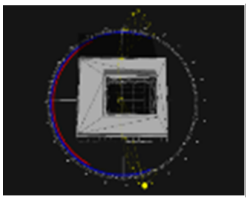
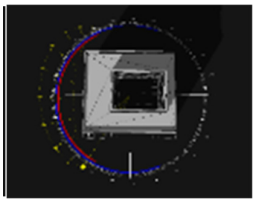
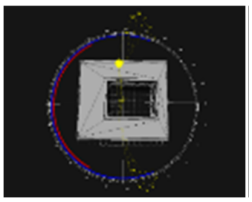
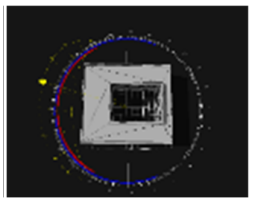
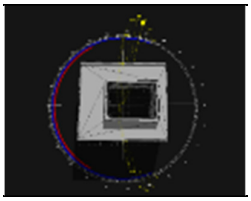
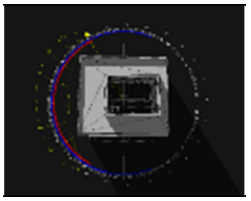
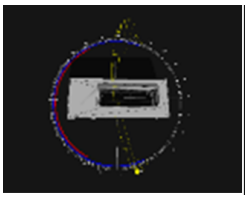
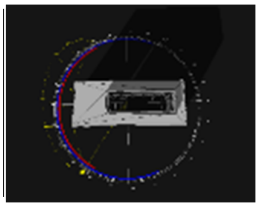
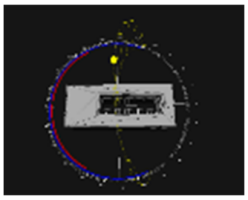
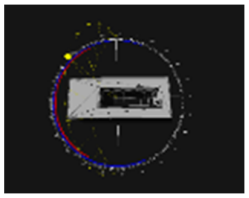
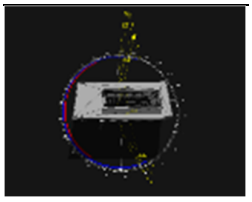
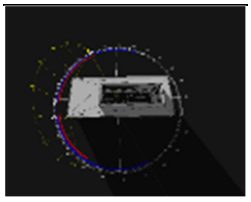
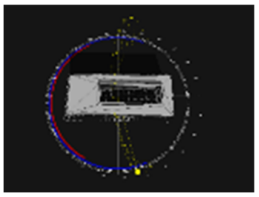
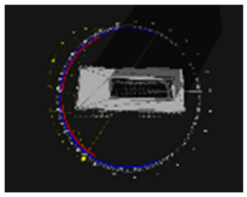
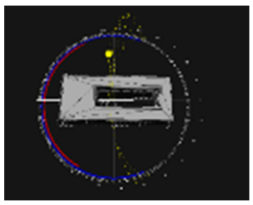
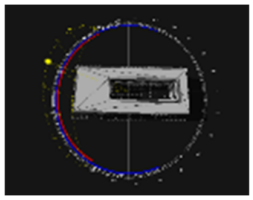
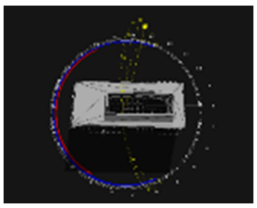
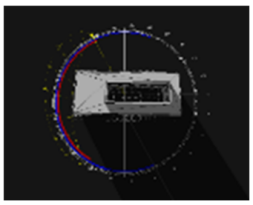
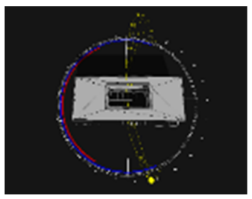
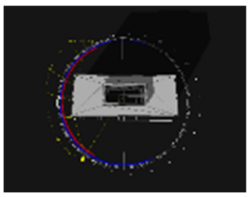
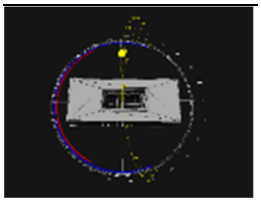
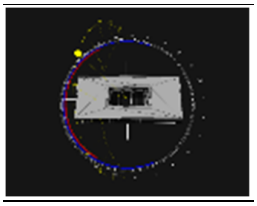
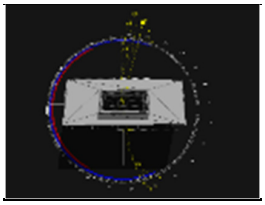
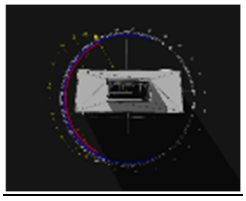
	Time	Picture	Summer	Winter
Courtyard 1	8 a.m.–10 a.m.			
	1 p.m.–2 p.m.			
	4 p.m.–5 p.m.			
Courtyard 2	8 a.m.–10 a.m.			
	1 p.m.–2 p.m.			
	4 p.m.–5 p.m.			

Table 3. The 3D simulation models for Courtyards 3 and 4.

	Time	Picture	Summer	Winter
Courtyard 3	8 a.m.–10 a.m.			
	1 p.m.–2 p.m.			
	4 p.m.–5 p.m.			
Courtyard 4	8 a.m.–10 a.m.			
	1 p.m.–2 p.m.			
	4 p.m.–5 p.m.			

Courtyard 1 is a 5.5 × 7.5 m floor area, located at the front entrance and easily accessible to all students as they enter the campus. The following images track the shadows across a summer day in June. During the beginning of the earliest class of the day, at 10 a.m., and the end of the day, at 5 p.m., most of the courtyard is shaded. However, during the lunch hour at 1 p.m., only about one third of the courtyard shaded. This makes courtyard 1 an undesirable location for lunch breaks during the summer months of June, July, and August.

The conditions in the winter months are far more favorable. More than half of the courtyard is shaded throughout the day. However, Courtyard 1 is still an unfavorable location for lunch because of its proximity to the main entrance and the security desk.

Courtyard 2 is a 3.5 × 11.5 m floor area, located near the Fine Arts studios. It is frequently used by students for socializing, spray painting, and other messy activities.

In the early morning, 8 a.m., Courtyard 2 is fully shaded. The same shading occurs at 5 p.m. During lunch hours (i.e., 1 p.m. to 2 p.m.), more than half of the courtyard is shaded, allowing students to occupy it with minimal discomfort from the sun. During the winter months, the conditions are extremely favorable, being fully shaded throughout the day. The following images track the shadows through the summer and winter months.

Courtyards 3 and 4 are almost identical in their conditions during summer and winter. The floor area of Courtyards 3 and 4 are 3.5 × 11.5 m. Both courtyards are fully shaded at the beginning of the day at 8 a.m., then move to three quarters of shade during the lunch hour. Then at 5 p.m., they are fully shaded once again. During the winter months, the courtyards enjoy a few extra centimeters of shade during the lunch hour. Images of the shadow changes across the day can be seen in the following images for both Courtyard 3 and Courtyard 4.

Regarding courtyards 5, 6, 7, and 8, the size of the shadow is mostly similar. The direction of the shadow differs in orientation depending on the location of the courtyard and its dimensions.

When the sun is at a lower angle (8 a.m.–10 a.m.), the shadows are covering the courtyard completely throughout the year. This provides a comfortable atmosphere. However, the occupancy is low during this time, as most students and faculty arrive to prepare for their first class of the day. At 1 p.m., the sun is theoretically at its highest angle and therefore the shadows are very small. This marks the start of the lunch hour. December provides the most preferable weather and shadows for occupancy, with three quarters of the courtyard being shaded. June has both the hottest weather and the smallest shadows. Therefore, during June, the courtyard is at its the lowest occupancy.

When the lunch hour ends (i.e., 2 p.m.),the results are similar to the analysis at 1 p.m. The shadows in December extend to cover the whole courtyard. During summer, half of the courtyard is shaded, which is the least during this time. This time is overall preferable for occupancy; however, it is the end of the lunch break as many students and faculty will be returning to class.

Between 4 p.m. and 5 p.m., the end of classes, we see conditions that are very similar to 8 a.m. The shadows extend to cover the whole courtyard throughout the year. However, visibility is low during this time due to the sunset and the minimal lighting within the college.

Overall, with the renovation proposed for the courtyards, the aim is to increase the usage of the courtyards during the year. The seating provided will encourage congregation and the shading strung up will block the more severe sunrays at the lunch break during the summer months.

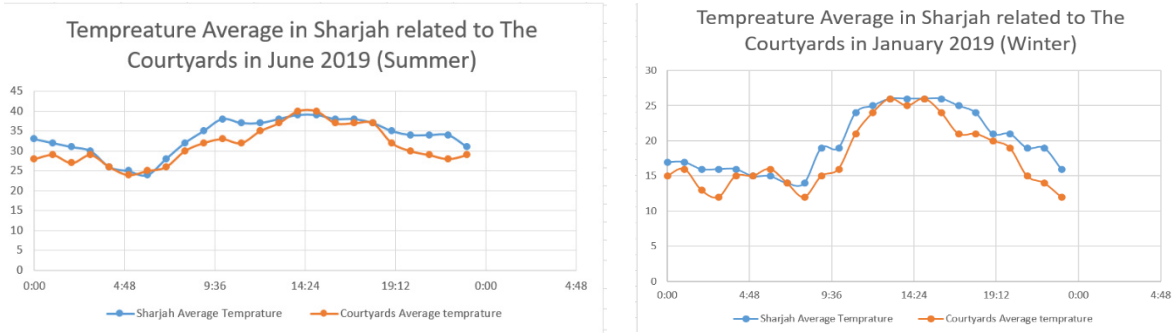
4.1.2. Comparative Thermal Analysis

In order to provide a thermally comfortable area for students, the temperature and humidity of the courtyards should be measured. Temperature is an important environmental factor that can significantly influence the courtyards' performance. Figure 3 determines the average temperature of the eight courtyards recorded in summer (i.e., June) and winter (i.e., January) throughout the day. It is clearly observed that the temperature outside the courtyards is higher than the temperature inside the courtyard throughout the day.

In summer, the peak reaches its maximum point during lunch time (1 p.m.–2 p.m.) when it is the hottest and has the lowest shading levels, 38 °C particularly. Similarly, the highest temperature recorded was between 1 p.m. and 2 p.m. in winter, 23 °C particularly. All the courtyards are covered; this reduces the courtyards' temperature in summer and winter. The presence of greenery and landscaping provides high shading levels, which improves the thermal conditions of the courtyards and decreases the inner temperature of the courtyards. As a result, the courtyards' temperatures are lower than Sharjah's temperature.

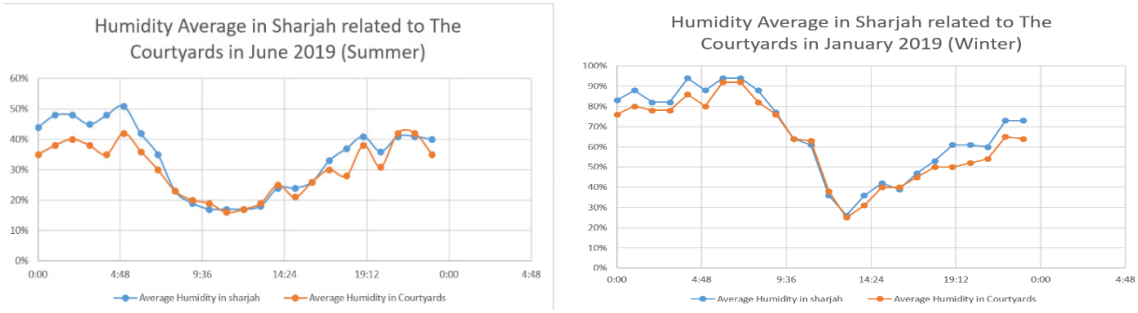
In terms of humidity, low humidity levels were recorded during the daytime, and high humidity levels were recorded during the nighttime. Figure 4 shows that the courtyards'

performance in June is better during daytime, specifically from 8 a.m. to 3 p.m. Additionally, the humidity reaches the highest percentages early in the morning and late at night in June and January. In January, Figure 4a shows no huge difference in the humidity level. As seen in Figures 4 and 5, the relationship between temperature and humidity are inversely proportional. The higher the air temperature, the lower the humidity.



(**a**) (**b**)

Figure 4. (**a**) Temperature average in Sharjah related to the courtyards in June 2019 (summer); (**b**) Temperature average in Sharjah related to the courtyards in January 2019 (winter).



(**a**) (**b**)

Figure 5. (**a**) Humidity average in Sharjah related to the courtyards in June 2019 (winter); (**b**) Humidity average in Sharjah related to the courtyards in January 2019 (summer).

In the next section, the social aspects of monitoring the courtyard performance are presented. The social aspects should not be considered less than the environmental aspects. Two surveys were distributed to all students from different year groups (freshman, sophomore, etc.). First survey was distributed before redesigning the courtyards to mainly determine the general performance of the courtyard. The second survey was distributed to measure the performance after developing those courtyards and whether students are compelled to access the courtyards or not. The results of participants were considered after and before redesigning the courtyards, which consequently concludes that redesigning the courtyards will indeed improve the social aspects.

4.2. Social Performance Indicators

Based on the nature of the College of Fine Arts and Design, the courtyard buildings provide space, a natural source of sunlight, and heat in winter. After redesigning the courtyards, benches and decorations were added and vegetation areas increased. In addition, shading layers were hung on the roofs of courtyards to increase their shading level. After redesigning, the survey was distributed to students, 67 students responded, 54 females and 10 males. Out of the 67 respondents, most of the participants were in their final year of study, particularly 30 students (Figure 6).

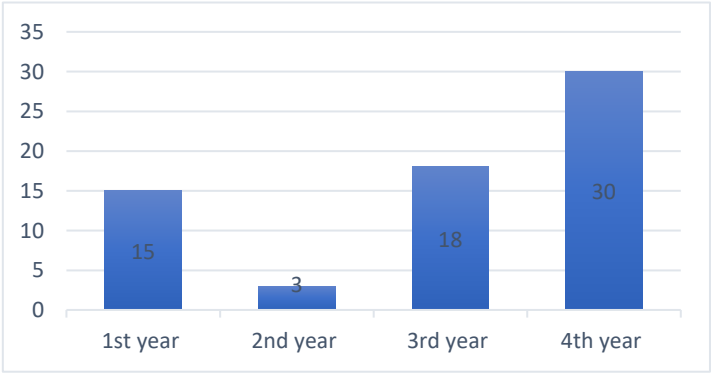


Figure 6. Distribution of respondents based on their year group.

As mentioned earlier, each courtyard was surrounded by one of the CAFD departments. Figure 6 is sorted by college departments to determine any connection between the proximity of the departments' instruction studios and the courtyard. The Fine Arts department students generally utilize courtyards more than other departments. A clear connection is realized between courtyards and the student studying Fine Arts. This correlation could possibly be due to the nature of the fine arts college where the students need open spaces and good lightning sources to produce innovative and creative works of art. In fact, Courtyard 2 is the most frequently used among the eight courtyards, as shown in Figure 7. The reason for this could be the presence of greenery areas and shaded benches available for students to sit on.

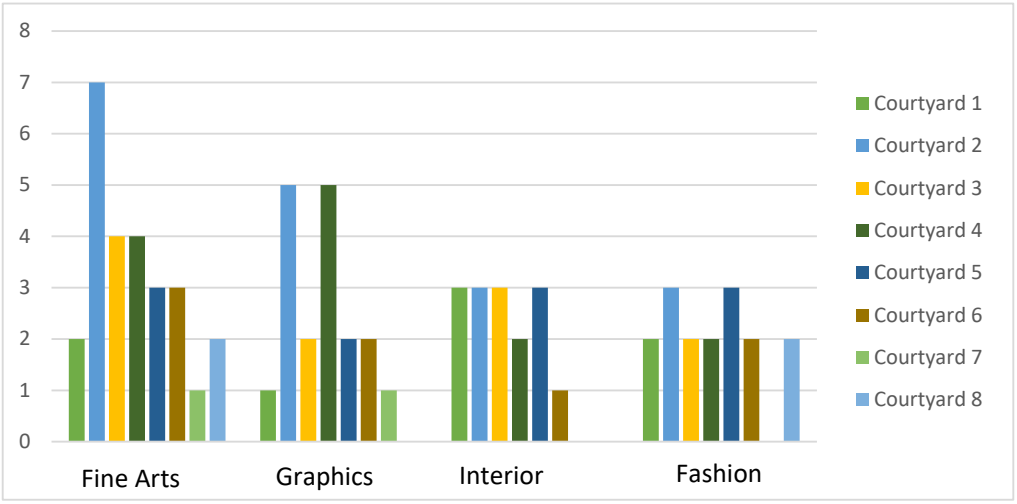


Figure 7. Connection between departments' instruction studios and the courtyard.

In order to obtain the best results of the redesigning, students were asked about what would encourage them to use the courtyards, and the results are presented in Figure 7. Due to the evacuation of courtyards, no one was able to access them. Therefore, as the access to courtyards was allowed, most students took advantage as shown in Figure 8. The low number of male respondents is a reflection of the overwhelming number of females. During the stage of redesigning, shades and vegetation were highly taken into consideration as most students highlighted their effect if they were present.

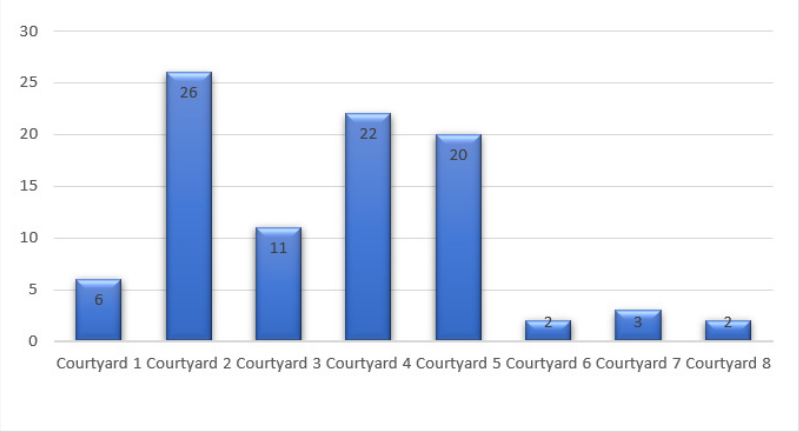


Figure 8. The number of students who accessed each courtyard.

When noticing the importance of shade to the students according to Figure 9, a question regarding the type of weather that would compel one to access the courtyards was put forth. The results seen in Figure 10 show a high number favoring the cloudy and cool climate. This is understandable in the hot and arid climate of the UAE, as mentioned earlier. However, more than half of the respondents favor a climate with sun or warmth. This is most likely due to students escaping the oppressive cooling of the AC to a more tempered climate outside.

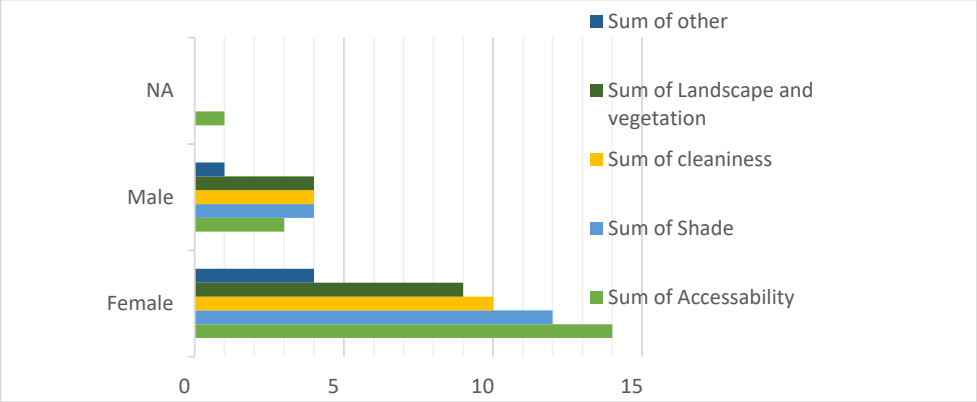


Figure 9. Reasons encouraged students to access the courtyards.

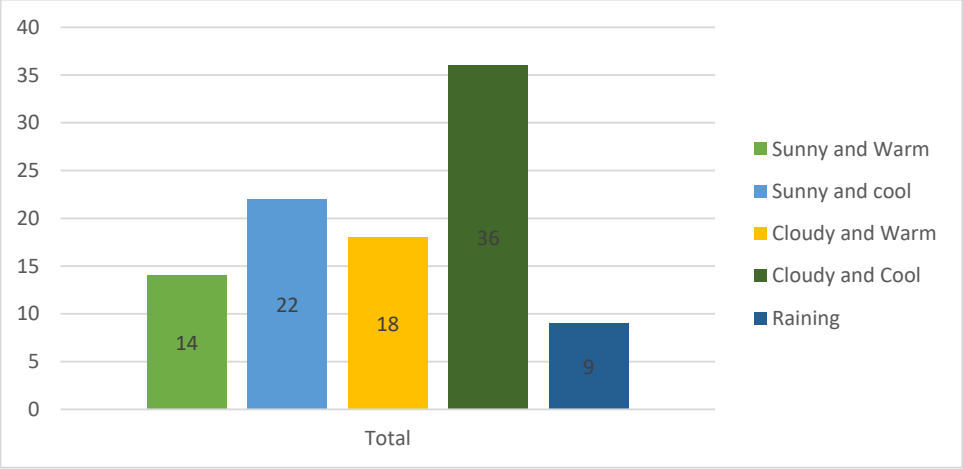


Figure 10. Type of outside weather that would compel students to access the courtyard.

After considering all the responds of the participants in the redesigning stage, another survey was distributed to students. The students were asked to select the type of activities preformed when they access the courtyards (Figure 11). It is clear that the improvements made in the courtyards affected the behavior of students where they do several activities. The top three activities performed by students who accessed the courtyards: rest alone, accompany, and enjoying the scenery. Further improvements have enhanced the social life of students and encouraged the access of students.

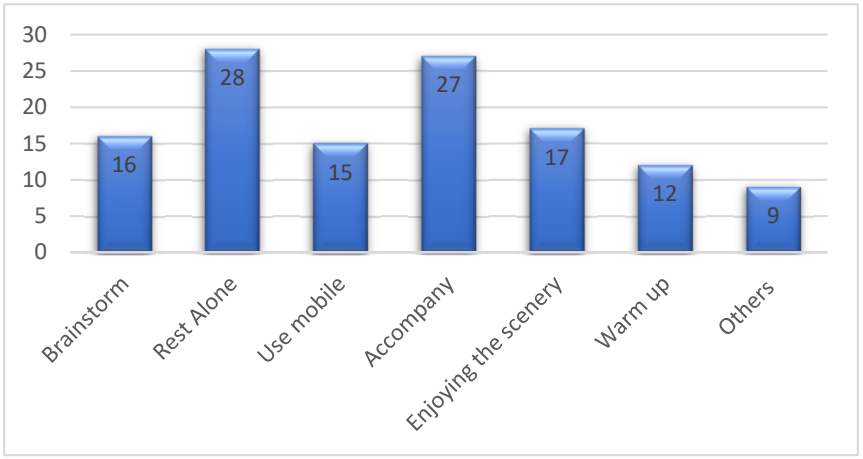


Figure 11. Type of activities preformed when accessing the courtyards.

For further improvements, another question was added in the survey to measure to what extent students would access the courtyard if greenery and foliage were present and if comfortable seating were present (Figure 12). Most students have totally agreed on the presence of greenery and seats in the courtyard.

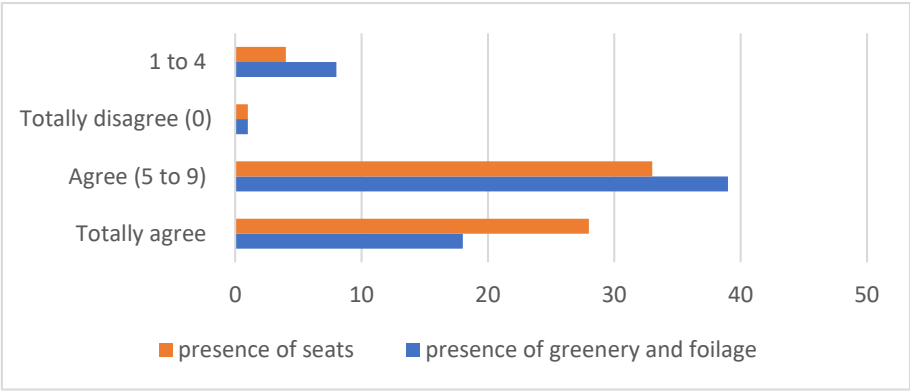
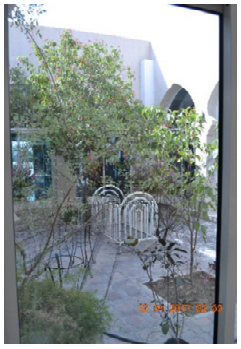
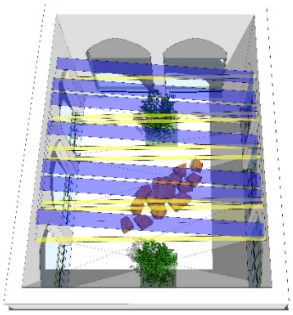
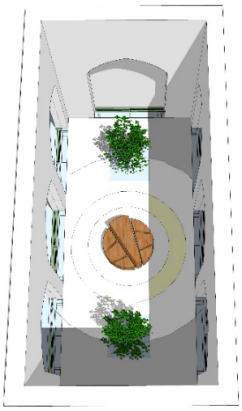
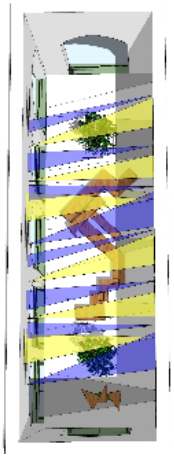
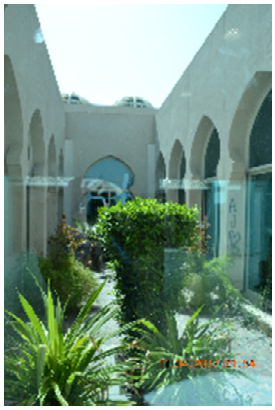
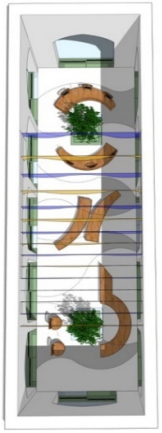


Figure 12. Would the presence of comfortable seating and greenery areas compel students' access to courtyards?

Table 4 displays the three stages of developing the courtyards buildings: documentation for existing courtyards, the proposed design, and post occupation.

Table 4. Photographs of the stages of redesigning the courtyards of CAFD.

	before Occupation	Modelling	after Occupation
Courtyard 1			
Courtyard 2			
Courtyard 3			
Courtyard 4			

5. Conclusions

According to the data analysis and classification of results, it is very clear that the main function of courtyards is to improve human comfort by modifying the microclimate around the building and enhancing thermal conditions. In addition, shaded courtyards and vegetation contribute towards improving the performance of the courtyard and the whole building.

In different proposals, the emotional effect of using awnings was to create more colorful shading and a green courtyard area inside the courtyard to improve and enhance the courtyard's performance.

In other words, people's behaviors and activities tend to be changed based on the building's performance if social aspects have been taken into consideration. Therefore, this study brings tension to discuss the importance of courtyards in terms of social aspects not only environmental aspects.

The main aim of the research paper, which is to evaluate the environmental and social impacts on unshaded courtyards integrated with occupants' interaction behavior, has been approved through the results that show that the integration of social aspects, such as adding seat benches in shaded areas and the growth of greenery, would improve the performance of the CFAD students. The presence of socialization spaces (i.e., courtyards) enhances the students' creativity and their social communications with the faculty members of the college. This study highlights the proposal for redesign the existing courtyards in education buildings to be socially and environmentally effective. At the same time, the paper figures out the link between the most important factors, thermal and social, to reactivate passive strategies and saving energy at the same time.

In future studies, the various components of passive strategies such as courtyards with shading, greenery, and with specific materials in the walls and floor of courtyards will be the focuses of research.

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