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Thermal comfort in open spaces in the arid climate of Kuwait: a study of construction training institute students

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---ABSTRACT---
This article assesses the students' sensation of thermal comfort in the open areas of the construction training institute in Kuwait, a hyper arid desert. This is carried out using field measurements from the site, and then handing out in-depth questionnaires to 100 students. The questionnaire provides great insight into the students' perception of thermal comfort, as well as the constituents that impact it. Moreover, the students' recommendations to improve thermal comfort in open spaces sheds light on the various methods that should be further researched and quantified. These solutions include adding substantial vegetation and trees for shading and redesigning the inadequate existing shading devices on campus. Overall, the findings indicate that the air temperature and humidity are well below the comfort level. These field measurements are sufficiently validated with the questionnaire results that indicate a substantially negative experience. While outdoor thermal comfort is heavily under researched in Kuwait, there are endless opportunities for improvement and development. Consequently, this paper acts as a catalyst for future endeavors, quantitative analysis, and raised awareness.

Keywords: *Thermal comfort, open spaces, Kuwait, educational institutions, shading devices*

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I. Introduction

Climate change's deteriorating consequences have led to an increased frequency and intensity of extreme weather events (Consequences of Climate Change - European Commission, n.d.). The climate crisis, coupled with the rise of urbanization, has made thermal comfort an utmost priority to account for. Hence, it has emerged as a significant topic that intrigued many researchers over the past few years. Thermal comfort is the psychological state that describes how satisfied an individual is within a local environment (Kumar & Sharma, 2022). The well-versed topic of thermal comfort and the satisfaction of the users in a particular space is highly significant. It is deemed especially significant in environments like Kuwait's – a hyper arid desert. The country's short winters and long summers experience maximum daily temperatures that reach 450C in the summer (World Bank Climate Change Knowledge Portal, n.d.). Such an extremely hot and arid climate makes it essential to account for the thermal comfort of the space users.

While typically within such environments indoor spaces dominate, it is nearly impossible to eliminate open spaces. Thus, it is vital to consider a multitude of solutions to improve the thermal comfort of these open spaces. Kuwait government has ardently worked on implementing innovative initiatives to cool people in open spaces, such as the addition of green areas. Part of Kuwait Vision 2035, the country aims to develop a sustainable living environment (MOFA | Kuwait Vision 2035 "New Kuwait, n.d.). Open spaces within educational buildings like schools and institutions are critical to consider; not only are they crucial for providing an outdoor environment but they also present a substantial case of thermal comfort. Ensuring that the students are well-ventilated and shaded whilst spending time outdoors is vital. As a result, a considerable amount of research on thermal comfort in educational buildings has recently emerged.

Some of the research addressed the indoor thermal comfort of school buildings in Kuwait, and found that 33% and 22% of the schools had temperature and humidity levels not within the recommended comfort levels, respectively (Al-Hubail & Al-Temeemi, 2019). Similarly, (Al-Rashidi et al., 2009) examined the indoor thermal comfort of pupils between the ages of 11 and 17, deducing that the various thermal comfort indices under-estimated the actual 'comfortable' values for the students. Moreover, (Al-ajmi, 2020) conducted a field study on the indoor thermal comfort of university campus buildings in Kuwait. The conclusions highlight the significance of adequate air conditioning design in educational buildings. It is evident that most of the research in Kuwait is limited to indoor thermal comfort and does not address the outdoor thermal comfort of open spaces within educational buildings. Hence, this lack of research on outdoor thermal comfort provides a clear need for further discussion on the neglected open spaces in educational and training institutions. In line with this, the aim of this research is to evaluate and improve the students' sensation of thermal comfort in the open areas of the construction training institute in Kuwait.

II. Methodology

This research uses various methods to test the existing and potential thermal comfort of the construction training institute in Kuwait. First, the present thermal conditions of the outdoor areas will be evaluated by field measurements in different shaded locations throughout the educational premises. Next, a questionnaire targeting 100 students on the construction training institute campus will be carried out. Aiming to gain a better understanding of the students' satisfaction and experience with the open spaces, the questionnaire results will be tallied and analysed.

The aim of this analysis is to assess the dire climate conditions and the need for solutions that alleviate the thermal comfort of these open spaces. Both the field measurements and the student questionnaire work together to evaluate and verify the climate conditions and thermal comfort. The above methods are all aligned to achieve the research aim, as well as provide valuable insight into Kuwait's educational campuses' outdoor thermal comfort.

III. Results and Discussion

In line with the research methodology, an extended thermal outdoor comfort questionnaire was distributed to 140 random male students. More than half of the respondents (52.49%) are from the 20-29 age group, followed by 27.97% from the 30-39 age group, and 6.39% from the 40-55 age group. Whilst only 13.48% are 18-19 years old, the questionnaire had a wide range of age groups amongst the respondents. The questionnaire is made up of eighteen questions, composed of demographic, multiple choice, open-ended, and Likert scale question types. These questions are structured as follows: two demographic questions, followed by an in-depth question about the perceived environmental conditions, and questions about the activity level, shade availability, hydration status, dust in the air, green areas and the cooling effect, thermal comfort vote, adaptive behaviors, health impact, perceived air quality, noise level, visual comfort, and overall satisfaction. It is concluded with two open-ended questions about suggested solutions and additional comments. The questionnaire is structured in a unique way to best understand the level of thermal comfort and satisfaction perceived by the students.

The filed measurements, taken on the same day as the questionnaire handouts, revealed that the humidity was 25% and the air temperature was 45 ^{0}C, which are well below the comfort level.

Validating this conclusion, the questionnaire results, as shown by Figure 1, convey that 44.68%, 21.99%, and 24.82% of students perceived the air temperature in the outdoor environment to be very hot, hot, and neutral, respectively. This result verifies the need to further investigate potential ways to alleviate the perceived air temperature in outdoor open spaces. Figure 2 reveals that 41.14%, 38.3%, 11.35%, and 9.22% of the respondents feel that the air temperature affects their overall comfort significantly, moderately, slightly, and not at all, respectively. These values demonstrate that the majority of the students feel discomfort to some extent regarding the effects of the current air temperature.

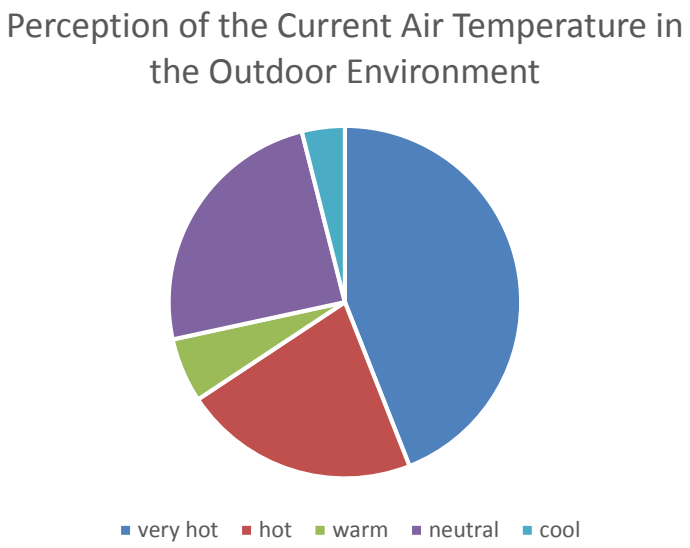

Figure 1: The students' perception of the current air temperature in the outdoor environment reveals that most of the students feel warm to very hot.

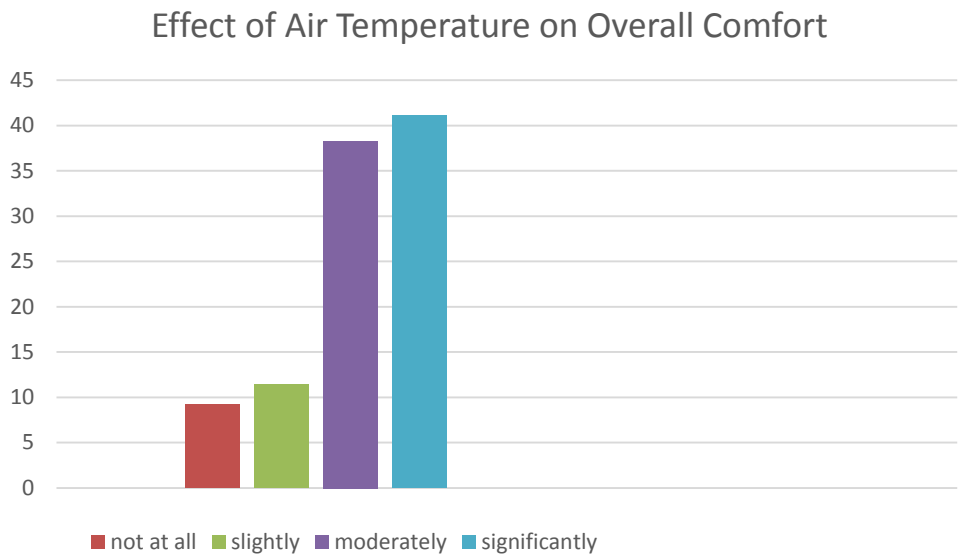

Figure 2: The students' perception of the effect of air temperature on their overall comfort shows that most of the students experience a negative effect.

Similarly, Figure 3 reveals that 9.93%, 9.93%, 7.8%, 24.11%, 26.95%, 12.77%, and 8.51% of the students found the humidity level to be very dry, dry, slightly dry, neutral, slightly humid, humid, and very humid, respectively. Moreover, as illustrated by Figure 4, 25.53%, 31.91%, 7.8%, 17.02%, and 17.73% of the students reported that the current humidity level affects their overall comfort significantly, moderately, not at all, slightly, and neutrally, respectively. These values indicate that while humidity levels may be perceived differently by the students, it is clear that it is causing significant discomfort. The students' perception of the air temperature and humidity is a testament to the pressing need for more research, experimentation, and implementation of solutions to this challenge. In terms of solar radiation perception (Figure 5), a staggering 53.19% of students mentioned that they were in direct sunlight, whereas only 5.67% and 41.14% were completely and partially shaded, respectively. Since more than half of the students were in direct sunlight, this calls for the need to design and implement more shading devices across educational premises.

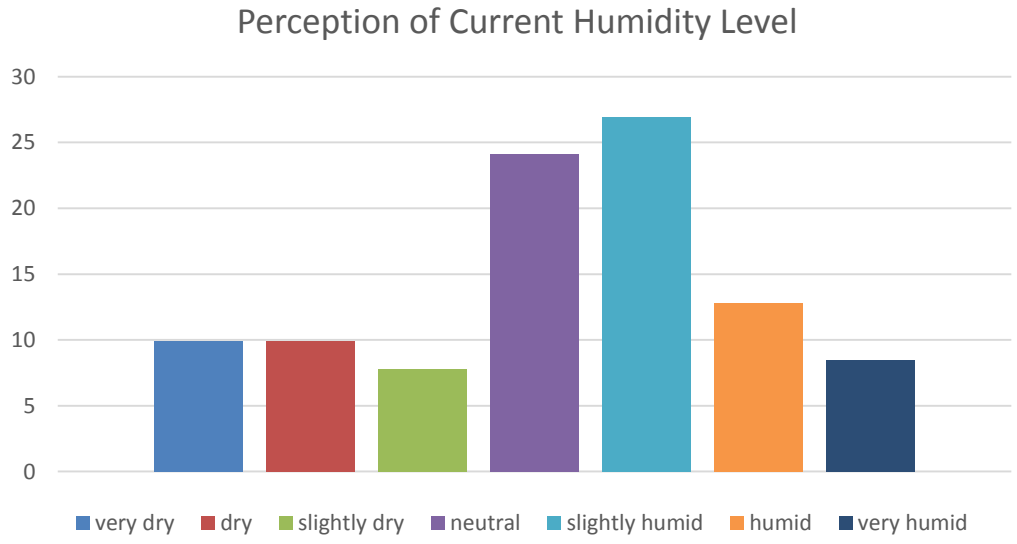

Figure 3. The students' perception of the current humidity level, revealing that the majority are not comfortable within the current conditions

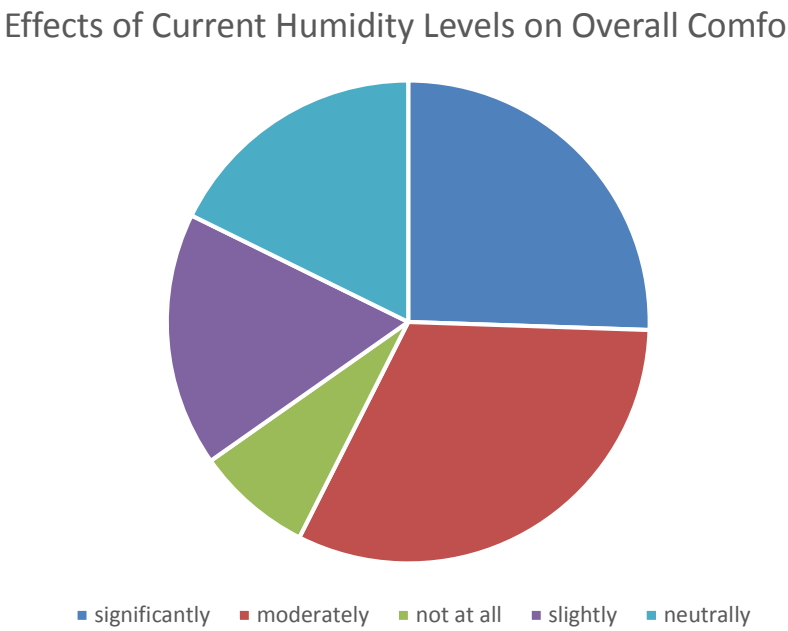

Figure 4. The effects of the current humidity levels on the students' overall comfort.

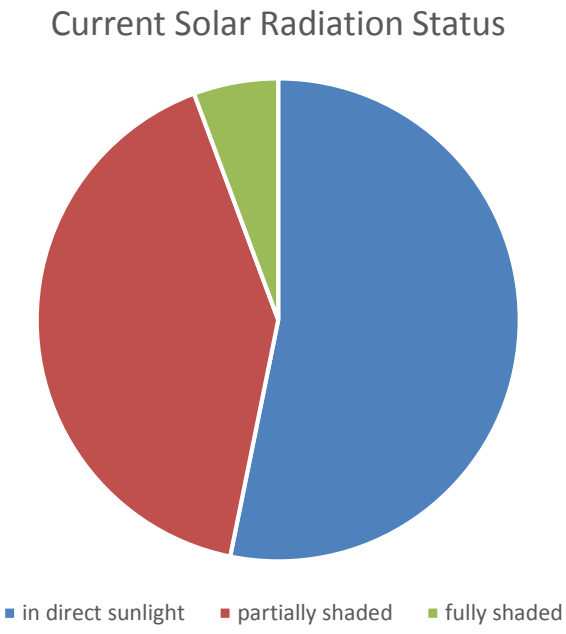

Figure 5. The students' current solar radiation status reveals that more than half of the students were in direct sunlight.

To better understand the context of the training institution, a few questions were asked regarding the clothing insulation type and current activity. As shown by Figure 6, 31.91%, 41.85%, and 26.64% of the respondents were dressed in heavy clothing (e.g., multiple layers, protective gear), medium clothing (e.g., light-colored long sleeves, pants), and light clothing (e.g., loose, light-colored clothes), respectively. In addition to that, Figure 7 shows that 47.52%, 20.57%, 17.73%, and 14.18% of the students were sitting/resting, working outdoors, walking, and exercising, respectively. Moreover, when asked about how much time the students spent in shaded areas within the last hour, as revealed by Figure 8, 33.33%, 34.75%, 9.33%, and 21.99% answered with 0-15 minutes, 15-30 minutes, 30-45 minutes, and 45-60 minutes, respectively. In terms of hydration status, 36.17% responded by verifying that they had not stayed hydrated within the last hour, whereas 63.83% did stay hydrated within the last hour (Figure 9). Consequently, due to the varied potential student outdoor activity

levels, clothing insulation types, and hydration status, it is significant to design a thermally comfortable outdoor experience while taking these variables into consideration.

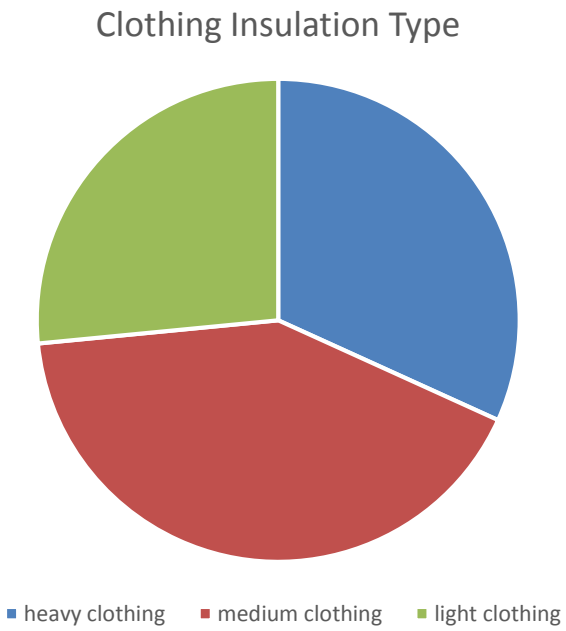

Figure 6. The students' current clothing insulation type during the time of the questionnaire.

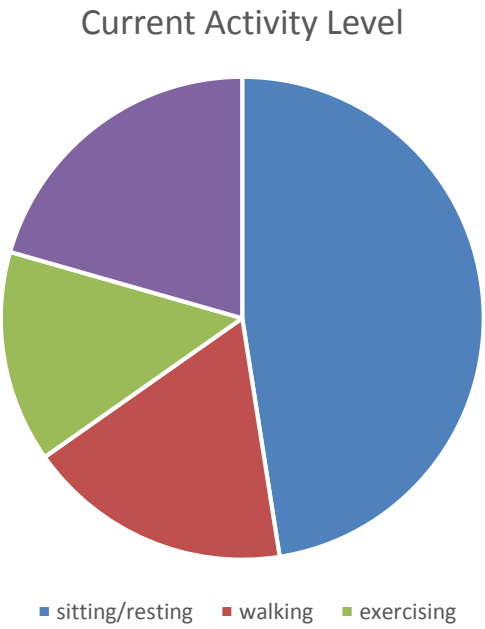

Figure 7. The students' current activity level during the time of the questionnaire.

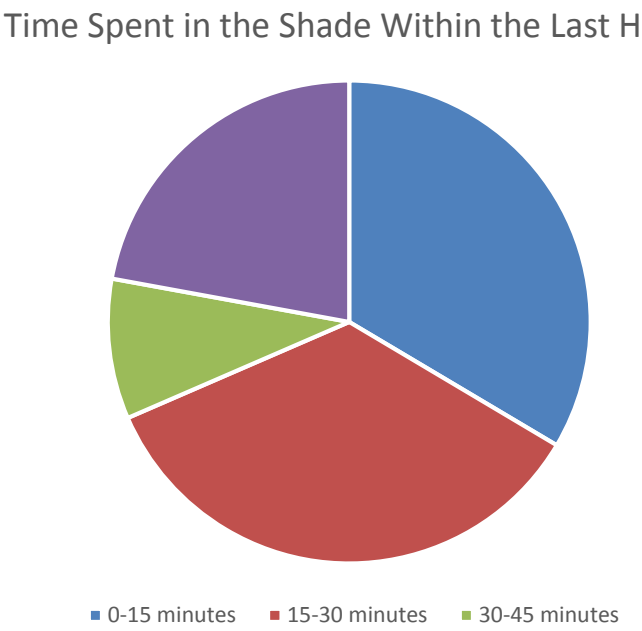

Figure 8. The amount of time spent by the students in the shade during the last hour.

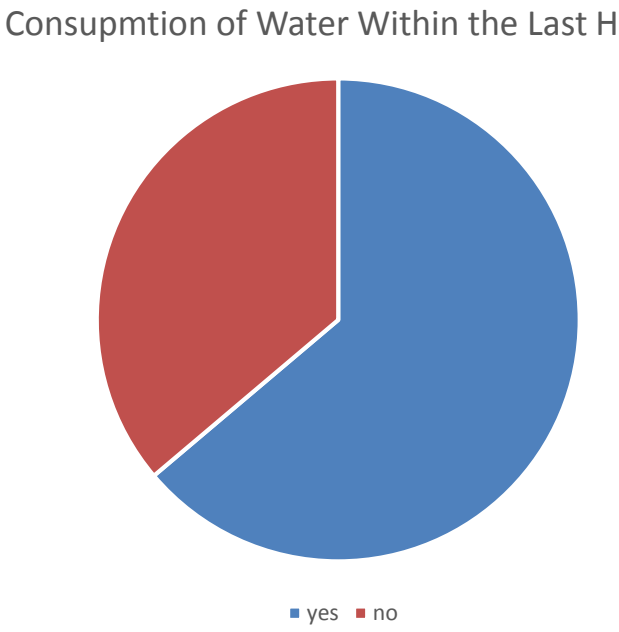

Figure 9. Students' responses on whether they consumed water within the last hour or not.

Dust can play a pivotal role in the deterioration of thermal comfort perception among individuals, as it is not only environmentally irritating but can also contribute to higher absorbed solar radiation (Algarni & Nutter, 2015). Therefore, the students were questioned on dust perception in their environment. Out of 56.74% of students that noticed dust in the air in the current location, 37.59%, 30.5%, 19.15%, and 12.77% felt that dust affected their overall comfort significantly, moderately, slightly, and not at all (Figure 10). Despite the overwhelmingly negative dust perception, only 34.75% took preventive measures to combat the dust, such as wearing a facial mask, and staying indoors. Consequently, this conclusion sheds light on the need for more awareness about practical preventive measures that students could take to lessen the negative impact of dust in the air.

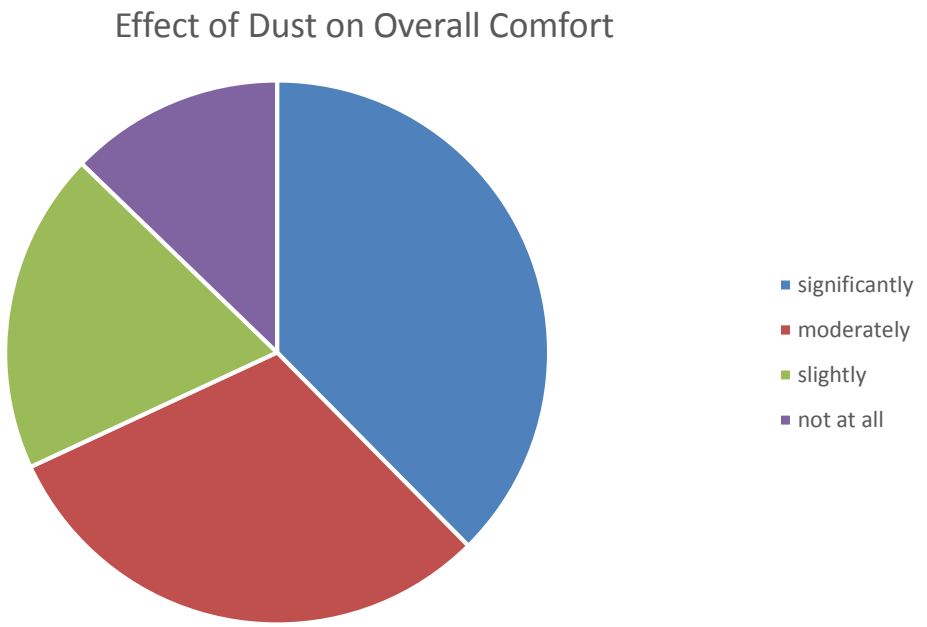

Figure 10. The students' perceived effect of dust on their overall comfort.

To measure the students' knowledge of green areas and the cooling effect, the results from the correlated questions reveal 78.72% believed there are not enough green areas to provide shade in the area (Figure 11). Additionally, as shown by Figures 12 and 13, 72.34% and 95.75% feel that greenery effectively cools the air around them and suggest adding green areas to enhance the thermal comfort, respectively.
Moreover, as Figure 14 demonstrates, 18.44%, 23.4%, 20.57%, 29.08% of the students voted the thermal comfort to be neutral, slightly uncomfortable, uncomfortable, and very uncomfortable, respectively.

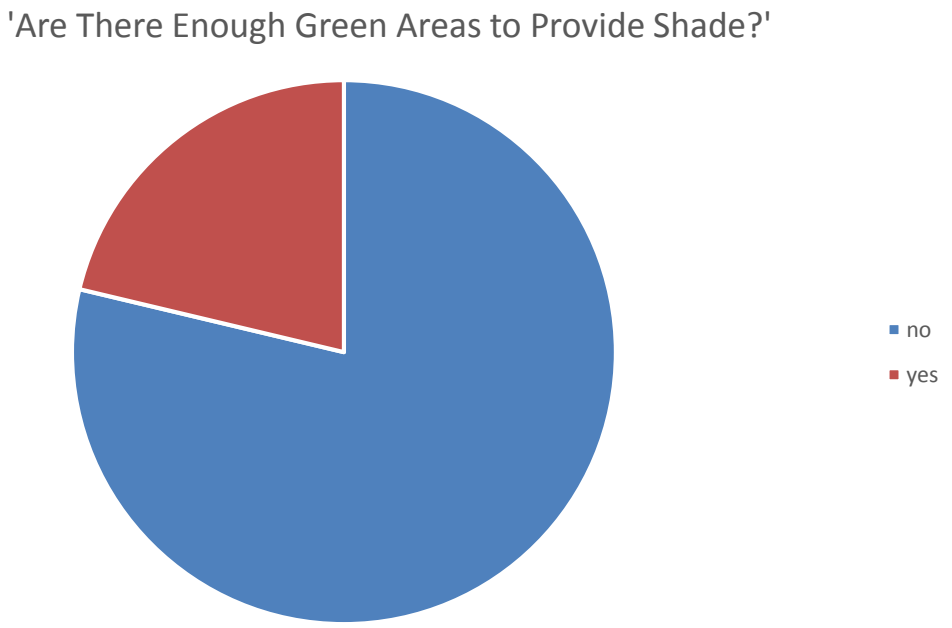

Figure 11. The students' responses to the question of green areas' adequacy in providing shade in the outdoor environment.

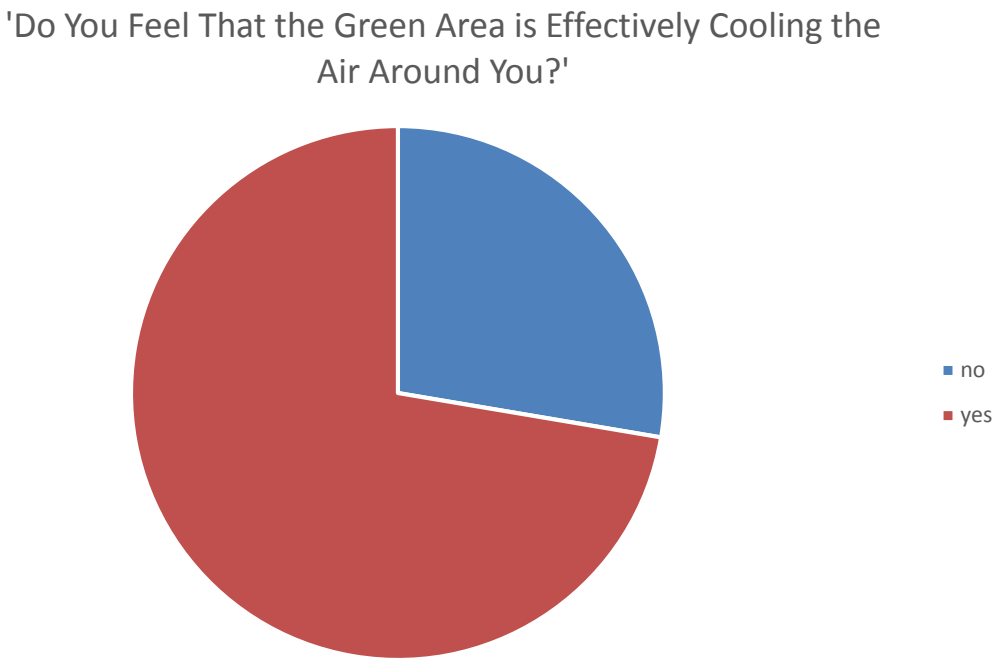

Figure 12. The students' responses to the question of green areas' effectiveness at cooling the air around them.

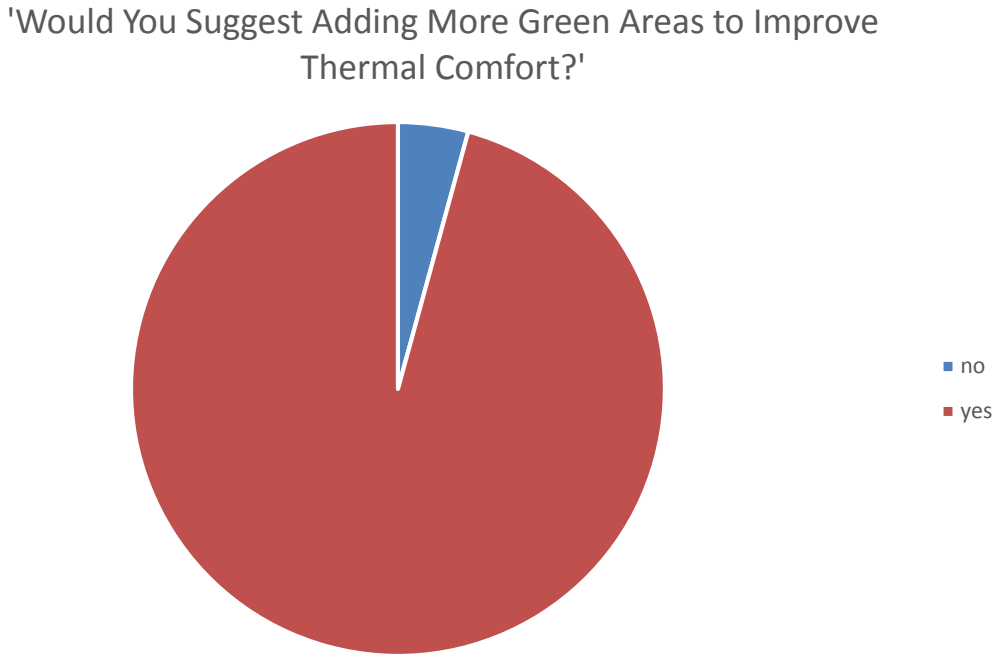

Figure 13. The students' responses to the possibility of suggesting the addition of more green areas to improve thermal comfort.

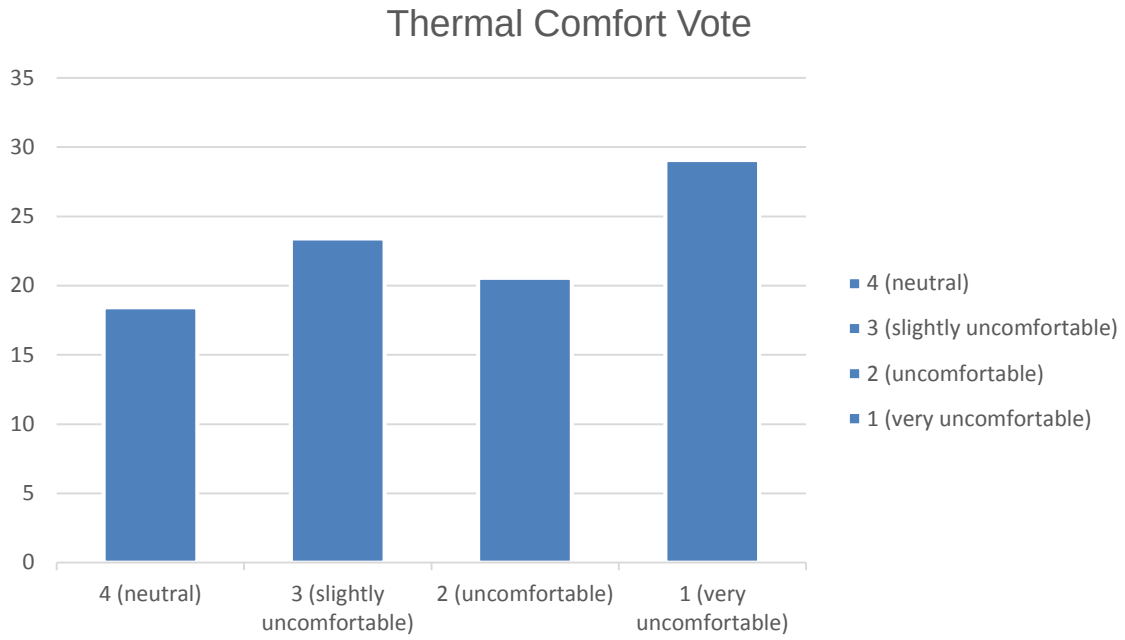

Figure 14. Students' thermal comfort vote, based on a scale from 1-7.

The most recurring adaptive measures that the students took to improve their thermal comfort were seeking shade, drinking water, changing clothing, reducing physical activity, and moving indoors. Despite taking adaptive measures, the inevitable negative health impact is evident in the most recurring symptoms experienced by the students due to the heat: fatigue, excessive sweating, and headache. These responses present a crucial inference; thermal comfort significantly impacts the comfort, health, and overall wellbeing of students at a training facility.

Next, the students' perceptions of air quality, noise levels, and visual comfort were surveyed. 0.71%, 0.71%, 41.14%, 29.79%, and 27.66% of students perceived the air quality as good, very good, poor, very poor, and neutral, respectively. As for the noise levels, 26.95%, 12.77%, 44.68%, 14.18%, and 1.42% of students found it noisy, very noisy, neutral, quiet, and very quiet, respectively. Similarly, about 64.54% of respondents felt some level of discomfort due to glare or bright sunlight. The most recurring measures taken by the students to combat the uncomfortable glare were moving to a shaded area, wearing sunglasses and a hat or cap. After reading the students' feedback, it is clear that the majority of students are not comfortable in terms of air quality, noise levels, and visual comfort. Improving thermal comfort will help alleviate the overall negative impact faced by the students. Ultimately, an overwhelming majority of 90% of students are not satisfied with the outdoor thermal comfort (Figure 15). This all-encompassing value illustrates the clear research gap of outdoor thermal comfort in Kuwait. Recognition and awareness are the first measures taken to proactively combat this issue by implementing this thorough questionnaire

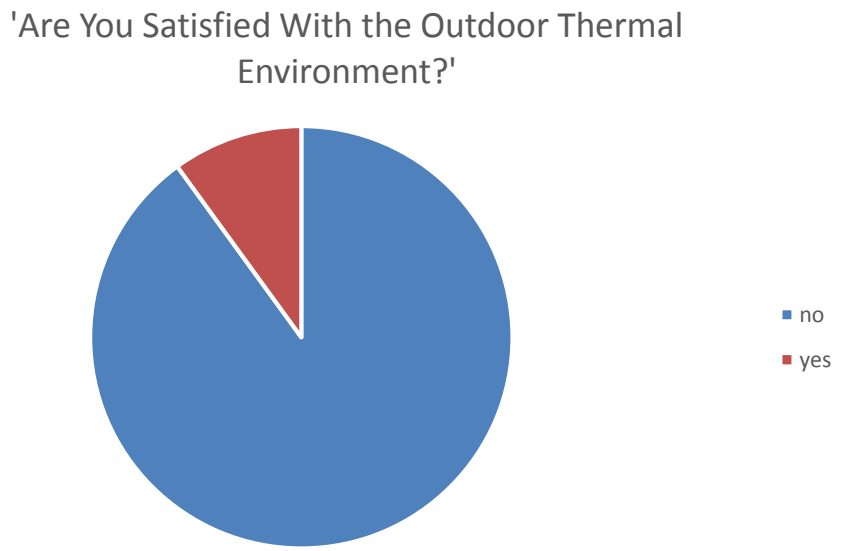

Figure 15. The students' responses to the question about the current satisfaction with the outdoor thermal environment, indicating that the overwhelming majority of students are dissatisfied.

Additionally, the open-ended question about the students' suggestions to improve the open spaces' thermal comfort provided great insight into the future directions. Most of the students mentioned that more greenery and vegetation should be used in these open spaces to provide sufficient shade. Some students also suggested designing new shading devices that are larger and cover expansive open areas. Other students were keener on changing the training uniform to a lighter, more breathable fabric. Other solutions included switching to indoor training sessions whenever possible, as well as providing a water supply to keep the students hydrated during the heat. These solutions pave the way for researchers and other professionals to experiment with innovative solutions to make educational spaces more comfortable to students in Kuwait.

IV. Conclusion

While the realm of thermal comfort in open spaces in Kuwait is insufficiently researched, this paper aimed to shed light on the students' perceptions of thermal comfort and the opportunities for future directions. The questionnaire played a pivotal role in raising awareness among the students, allowing them to analyze the current situation of open spaces in their institution. It acted as a catalyst, pushing the students to think proactively about the present conditions and future opportunities.

In the future, further research may outline quantitative results that are associated with improvements to open spaces in educational institutions in Kuwait. Additionally, energy analysis can help quantify predictions to thermal comfort improvement.

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