Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

Thermal Comfort Assessment of Classrooms in Engineering Colleges of Kathmandu Valley

Bilove Moktan [a], Sanjaya Uprety [b]

[a, b] *Department of Architecture, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a] bilovemoktan@gmail.com, [b] suprety@ioe.edu.np

Abstract
On average, engineering students spend about 6.5 to 7 hours in the classroom learning every day. Spending such long hours in the learning spaces, the thermal environment of the classrooms has a direct impact on both the well-being, and academic performance of the students. There are no design standards issued by the Nepalese government which address the issue of thermal comfort while designing or constructing educational buildings. Also, there have been very few studies regarding thermal comfort in classrooms of Nepalese Educational Buildings.

This study investigated the thermal comfort perception of students inside the classrooms of two engineering colleges: Kantipur City College (KCC) and National College of Engineering (NCE) in Kathmandu Valley during June-July of 2022. A questionnaire survey of students regarding their thermal sensation and preferences along with measurement of different thermal parameters inside the classrooms of both engineering colleges was performed. A total of 124 students aged between 20-24 years, 76 (61%) males and 48 (39%) females participated in the questionnaire survey. It was found that the indoor temperature in the classrooms ranges between 27-30℃, which is beyond the comfort temperature range of 18-26℃ in Kathmandu. Subjective analysis through the questionnaire survey revealed that the majority of the students from both colleges (74% in KCC, 84% in NCE) are not satisfied with the classroom's thermal environment, felt uncomfortable during the lecture hours, and preferred the classrooms to be cooler during the summer. Hence, the findings of this study indicate that it is necessary to improve the thermal comfort conditions in the classrooms.

Keywords
Thermal Comfort, Adaptive Nature, Passive Design, Free Running, Subjective Response

1. Introduction

Thermal comfort is essential in all building sectors, and more necessarily so in educational buildings. Indoor thermal environment is responsible for maintaining the comfort and well-being of the students in educational buildings. If thermal comfort is not maintained, it can have an adverse effect on the academic performance and productivity of students in the classrooms Most of the Nepalese educational buildings have either poor insulation or ventilation system i.e. they offer no significant relief or protection against severe heat during summer, or severe cold during winter, leading to difficulty in focusing and concentration during the study hours [1]. For a classroom to be thermally acceptable, more than 80% of the students should perceive it as so [2].

Numerous environmental factors, such as air temperature, relative humidity, air velocity, level of attire worn, the type of activity performed, etc., have an impact on how comfortable a student feels in the classroom [3]. Hence, these factors must be controlled either through passive or active strategies for creating favorable thermal environment in the classrooms. In naturally ventilated rooms, where people can open and close windows, their thermal response will be partially dependent on the outdoor climate and may have a wider range of comfort than in buildings with centralized heating, ventilation and air conditioning systems. There is much more flexibility for people to control indoor environmental parameters which can affect their thermal comfort in their personal homes or

offices. However, in a classroom environment, students are limited in what they can do to achieve thermal comfort such as changing their uniform, seating positions, or opening-closing windows [1].

There have been very limited indoor thermal environment studies conducted in Nepalese educational buildings. There is a serious lack of thermal comfort consideration in the design guidelines of school buildings [4]. This has led to both students and teachers being in uncomfortable learning spaces for extended periods of time, which negatively affects their well-being and productivity in the long run. Therefore, this study's primary goal is to assess the present thermal environment of the classrooms of engineering colleges in Kathmandu Valley and gather and analyze students' responses to the classroom environment.

2. Literature Review

With the advancement in technology and resources, people began regulating their living spaces according to their will, either at home or in offices in the twentieth century, and thus the need and idea of a pleasant and healthy environment were established [5]. The psychological condition of being satisfied with one's thermal surroundings is known as thermal comfort. At present, there are two primary models which are at focus while studying thermal comfort in any occupied space. Fanger developed the first steady-state model in the 1970s to study thermal comfort in spaces provided with air conditioning. This model takes into account the thermal equilibrium mechanism of the human body. There are two different indices: Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) used in this model to forecast the average perception of thermal comfort among a set of individuals and to find the percentage of individuals who might be or are discontent with their thermal spaces [6].

According to this theory, people are able to adapt to a wider variety of fluctuations in temperature, different weather conditions, or in areas than are typically thought to be comfortable [6]. This is due to the fact that in order to minimize any physical or psychological discomfort, the human body automatically tends to adjust itself in a new environmental setting. The major practice in performing thermal comfort studies which is, either in actual buildings or in spaces where both environmental and human variables can be monitored or regulated at will [7]. Controlling the environment inside actual structures or buildings is very difficult as various outside factors have a considerable impact on how the building performs thermally at any given instant. As a result, it is discovered that researchers are involved in incorporating both qualitative and quantitative measures for evaluating thermal comfort in different environments.

All over the world, research regarding thermal comfort in any occupied spaces follows the two primary principals. In majority of buildings in Europe, the Heat-balance model has found to be utilized. In contrast, the Adaptive thermal comfort model is found to be the preferred model while conducting comfort studies in different regions of Asia. Likewise, several other countries have incorporated these two methods in their building design standards, but the concept of thermal comfort is often excluded while designing academic facilities [7].

In any learning environment such as a classroom, there are number of elements which can obstruct the general comfort of students. This makes studying thermal comfort in academic institutions a bit more complicated and nuanced. As a result, different researchers such as [8] and [7] have frequently categorized their studies based on the unique features that a learning environment possesses. One of the widely used categorization is the level of education of the student. According to [7], the educational level can be divided into Kindergartens, Elementary/Primary schools, Secondary schools, and Universities. It has been proven that children who study in the lower levels are more susceptible to changes in the physical environment of the classroom as compared to adults who are much more capable of adopting to those changes. Conducting thermal comfort surveys among small children is also challenging as they cannot properly comprehend or express their exact thermal sensation or perception. Students in secondary schools or aged above 12 have the ability to provide more detailed answers about their feelings and preferences, and when necessary, they can also adjust their classroom environment by opening or closing windows, turning on or off fans, etc [7]. Also, how the classroom runs during the day also has a significant impact on how comfortable students feel in the classroom.According to [8], classrooms can be separated based on their mode of operation as: Non-ventilated or free-running

classrooms (without any HVAC equipment) and classrooms which are provided with air conditioning systems. In air-conditioned classrooms, the indoor temperature is constantly monitored and adjusted according to the needs of the occupants. But, in free running classrooms, the outside climatic factors such as relative humidity, wind speed, etc. have greater effect on the indoor environment. Hence, students in naturally ventilated classrooms have to adjust to varying degrees of thermal conditions in the classroom while studying.

A student spends most of his/her time in schools or colleges outside of their homes. Attending lectures or carrying out different academic activities in classrooms become an integral part of every student's daily life. There exists a strong relationship between the physical environment of classrooms and students' learning performance and health [9]. In order to improve the productivity, performance and well-being of students, thermal comfort has to be maintained in the classrooms. Several studies such as [10], [11], and [12] have clarified the importance of adaptive thermal comfort in educational institutions. Each learning space is unique and has its own set of requirements to achieve comfort. The comfort temperature in classrooms lying in different climatic regions may not be the same. The Adaptive comfort temperature has been described by Nicol as a temperature at which people find comfort in a given situation. In the case of Kathmandu, comfort temperature studies conducted by Nicol and Rijal, show that the adaptive indoor temperature in comfort temperature (Tc) is between 18°C and 26°C [13].

In the past few decades, thermal comfort in classrooms has become a popular subject of interest in international communities. Nepal has been lagging behind in this domain. Studies regarding thermal comfort in residential buildings can be found to be done by [14]. In the context of educational buildings, [15] have performed thermal surveys among students studying at the school level. One of the informative and detailed study done is by [1]. In this study, students of secondary level studying in different schools in the warm temperate climatic region of Nepal were questioned regarding their thermal comfort in the classrooms. The results found that majority of the pupils were generally comfortable in their respective classrooms, even if the classrooms were free running.

3. Methodology

3.1 Study Region

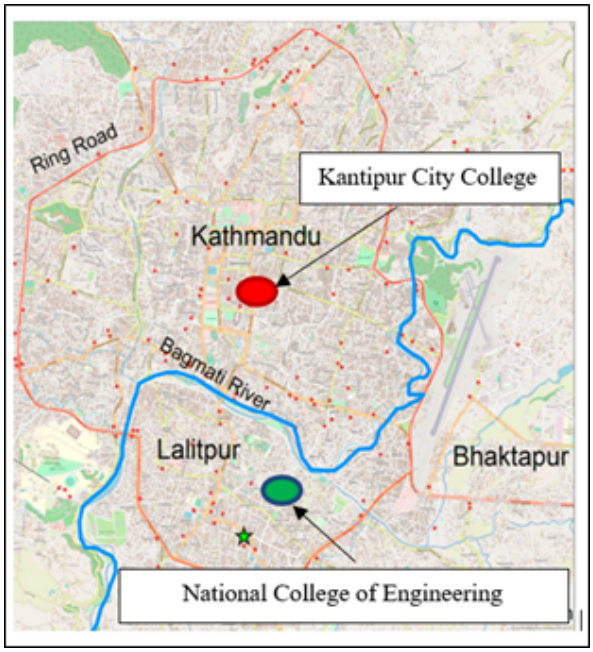

Figure 1: Study region showing surveyed colleges

A field study was conducted in the classrooms of two engineering colleges: Kantipur City College (KCC) located at Putalisadak, Kathmandu and National College of Engineering (NCE) located at Talchhikhel, Lalitpur in the months of June-July of 2022. The colleges lie in the warm temperate climate of Kathmandu Valley.

3.2 Classroom Description

The classrooms in both colleges are free running i.e. are naturally ventilated and can accommodate about 50 number of students at a time. The typical classroom size in KCC and NCE are 7.6 m x 5.25 m and 6.95 m x 6.05 m respectively. The walls are 230 mm thick with cement plaster, and light in color.

Windows facing east and south are provided in the classrooms which allow the entry of light, heat as well as air movement. Ceiling fans are also provided in the classrooms for cooling during the summer.

3.3 Thermal Measurements

The values of indoor air temperature, relative humidity, and air speed in the classroom were recorded during the field survey. The description of the devices used for recording these thermal data is shown in Table 1.

Figure 2: Classroom of Kantipur City College

Figure 3: Classroom of National College of Engineering

For data collection, the devices were positioned in the middle of the classroom, and readings were taken in intervals of 15 minutes between 1:00 p.m. and 2:00 p.m.

3.4 Questionnaire Survey

A semi-structured questionnaire survey was conducted in the classrooms during lecture hours. Votes were cast by the students regarding their level of feeling of comfort in the classroom. Their preferences for the classroom's indoor climate were also noted down. The teachers helped in making the students understand the questions more accurately and conduct the survey smoothly. The students were wearing lighter clothes, such as T-shirts/Shirts on the top and pants on the bottom, showcasing the adaptive behavior of the occupant. The questionnaire with sensation scales used in the study is shown in Figure 4.

Table 1: Information of Instruments Used

Parameters	Instruments Used	Range
Air Temperature	Thermo-Hygrometer	0-55°C
Relative Humidity		10-95%
Air Speed	Anemometer	0-30 m/s

1. How do you feel at this present moment in the classroom? (**Thermal Sensation**)

☐ Very Cold ☐ Cold ☐ Cool
☐ Slightly Cool ☐ Neutral ☐ Warm
☐ Slightly Warm ☐ Hot ☐ Very Hot

2. Your level of comfort inside the classroom during the lecture hours? (**Overall Thermal Comfort**)

☐ Very Comfortable ☐ Comfortable ☐ Slightly Comfortable
☐ Slightly Uncomfortable ☐ Uncomfortable ☐ Very Uncomfortable

3. Is the thermal condition in the classroom acceptable to you? (**Thermal Acceptance**)

☐ Yes ☐ No

4. What would you like the classroom to be? (**Thermal Preference**)

☐ Much Warmer ☐ A Bit Warmer ☐ No Change ☐ A Bit Cooler ☐ Much Cooler

Figure 4: Questionnaire used for survey

4. Results, and Discussion

The results of the thermal measurements reveal that both students and teachers are subjected to high temperatures in the classroom during the summer. The temperatures inside the classrooms between the time of 1:00 p.m. and 2:00 p.m. was found to be between 27°C and 30°C, while the outdoor temperatures were recorded to be between 28°C and 32°C. This showed that the classrooms did not offer significant protection from the outside heat in the summer.

In NCE, the highest temperature recorded was 30.8°C at 1:35 p.m., while the highest temperature in KCC was 27.3°C, which is relatively lower than that of NCE's. The higher temperatures in classrooms of National College of Engineering (NCE) maybe due to the large windows present in the south and east façades through which higher solar heat gains occur throughout the day. As the classrooms are naturally ventilated, the average relative humidity was found to be 58% which lies in the comfort range. The air speed was measured to be in between 0.1 m/s – 0.5 m/s for natural air movement

whereas it was found to increase to 1.8 m/s – 2.0 m/s when the fans were turned off.

4.1 Thermal Sensation and Preferences

In order to accurately measure the existing thermal sensation of the students in the classrooms, a modified 9-point ASHRAE scale was used as shown in Figure 4. According to the Fanger's thermal comfort model, the occupants are said to be satisfied with the thermal environment if they vote for the central three categories (Slightly cold, Neutral, and Slightly hot) on the TSV scale. In this study, majority of the students from both colleges (74% in KCC, 82% in NCE) voted for feeling hot, 14% in KCC, 10% in NCE voted for feeling slightly hot, and only 12% in KCC and 8% in NCE voted for feeling comfortable or neutral in the classrooms.

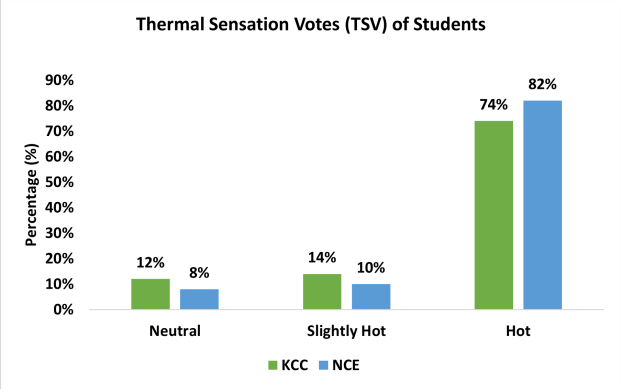

Figure 5: Distribution of Thermal Sensation Votes

4.2 Thermal Acceptance

Regarding thermal acceptability, a simple yes/no question was asked to the students to which about 88% of the total students answered that the thermal conditions were not acceptable in the classrooms. According to the ASHRAE standard 55, an indoor space needs to satisfy 80% acceptability level, these classrooms do not meet this criterion and are deemed to be as thermally uncomfortable.

4.3 Overall Comfort

The responses regarding the overall comfort on current classroom thermal environment is presented in Figure . Most of the responses in classrooms of both colleges were found to be more for uncomfortable (82% in NCE; 64% in KCC) and a small percentage for slightly comfortable (12% in NCE; 26% in KCC) and comfortable (6% in NCE; 12% in KCC).

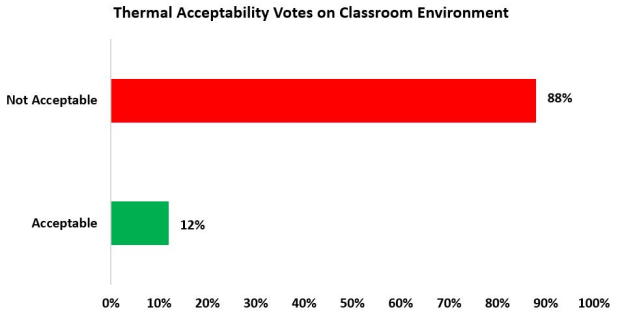

Figure 6: Distribution of Thermal Acceptability Votes

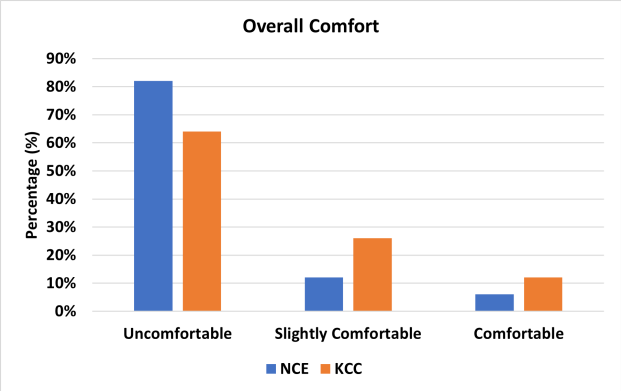

Figure 7: Distribution of Overall Comfort Votes

The main results and discoveries of this research are:

1. The classrooms in both colleges are quite hot during the summer. The indoor temperature in the classrooms ranges between 27-30°C, which is beyond the comfort temperature range of 18-26°C in Kathmandu.

2. The comfort levels in the classroom were low and undesirable according to the majority (88%) of the students. Hence, the students preferred changes to be made in the classroom to make it more comfortable to study during the summer.

5. Conclusion

In conclusion, the field study of the classrooms in two engineering colleges: National College of Engineering and Kantipur City College in the summer months of June-July in 2022 illustrated that the temperature in the classrooms was quite high (between 27-30°C), and beyond the adaptive comfort temperature range of 18-26°C. This was also validated by the responses obtained from the questionnaire survey which showed that the majority (74% in KCC, 82% in NCE) of the students felt "hot" during the lecture hours and preferred the classrooms to be more cooler.

6. Recommendations

From the results of this study, it is evident that further research should be done focusing on efficient strategies which would help to improve the thermal comfort of students in the classrooms, using either active measures such as HVAC, or passive strategies such as introducing shading, insulation, etc. This study only looked at the comfort level of students in the classroom, hence studies which also take into account the comfort of teachers while teaching in the classroom can be performed.

References

[1] Mishan Shrestha, Hom B Rijal, and Masanori Shukuya. Field study on adaptive thermal comfort in naturally ventilated secondary school buildings in nepal. *Journal of the Institute of Engineering*, 15(3):317–325, 2019.

[2] Sudeep Ghimire and Sushil Bahadur Bajracharya. A Study on Adaptive Thermal Comfort in Naturally Ventilated School Building in Kathmandu. In *Proceedings of IOE Graduate Conference*, volume 8, pages 690 – 695. Institute of Engineering, Tribhuvan University, Nepal, June 2020.

[3] Surya Rajkumar, Lilly Rose Amirtham, and Ebin Horrison. Thermal comfort assessment of a studio classroom in hot & humid climate conditions. In *ICUC9-9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment*, 2015.

[4] Nischal Chaulagain, Bivek Baral, and Saurav Raj Bista. Thermal performance of nepalese building-a case study of dhulikhel and biratnagar. *Journal of the Institute of Engineering*, 15(3):73–77, 2019.

[5] Kristian Fabbri. Indoor thermal comfort perception. *A Questionnaire Approach Focusing on Children; Springer: New York City, NY, USA*, 2015.

[6] Ricardo Forgiarini Rupp and Enedir Ghisi. Predicting thermal comfort in office buildings in a brazilian temperate and humid climate. *Energy and Buildings*, 144:152–166, 2017.

[7] Giulia Lamberti, Fabio Fantozzi, and Giacomo Salvadori. Thermal comfort in educational buildings: Future directions regarding the impact of environmental conditions on students' health and performance. In *2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)*, pages 1–6. IEEE, 2020.

[8] Manoj Kumar Singh, Ryozo Ooka, Hom B Rijal, Sanjay Kumar, Anuj Kumar, and Sadhan Mahapatra. Progress in thermal comfort studies in classrooms over last 50 years and way forward. *Energy and Buildings*, 188:149–174, 2019.

[9] Haiqiang Liu, Xidong Ma, Zhihao Zhang, Xiaoling Cheng, Yanmi Chen, and Shoichi Kojima. Study on the relationship between thermal comfort and learning efficiency of different classroom-types in transitional seasons in the hot summer and cold winter zone of china. *Energies*, 14(19):6338, 2021.

[10] Simone Secchi, Fabio Sciurpi, Leone Pierangioli, and Matteo Randazzo. Retrofit strategies for the improvement of visual comfort and energy performance of classrooms with large windows exposed to east. *Energy Procedia*, 78:3144–3149, 2015.

[11] Zahra Sadat Zomorodian, Mohammad Tahsildoost, and Mohammadreza Hafezi. Thermal comfort in educational buildings: A review article. *Renewable and sustainable energy reviews*, 59:895–906, 2016.

[12] Sita Bhusal. *Study of thermal comfort in Terai region Nepal–A case of school building in Kapilvastu district*. PhD thesis, Pulchowk Campus, 2021.

[13] Yam Prasad Rai. *Improving Thermal Comfort of Residential Buildings in Kathmandu using Passive Design Strategies*. PhD thesis, PhD thesis, University of Liverpool, 2014.

[14] HB Rijal, H Yoshida, and N Umemiya. Seasonal and regional differences in neutral temperatures in nepalese traditional vernacular houses. *Building and Environment*, 45(12):2743–2753, 2010.

[15] Shrestha Mishan and Rijal Hom Bahadur. Study on adaptive thermal comfort in naturally ventilated secondary school buildings in nepal. In *IOP Conference Series: Earth and Environmental Science*, volume 294, page 012062. IOP Publishing, 2019.