The Effect of Thermal Comfort in Educational Buildings during Hot and Dry Climate: A Case Study of Najran Climate Region

Badr Saad Alotaibi[1], Mohammed Awad Abuhussain[1], Yahya Murshid Al-Qurei[1], Yousef Hussain Al-Quraishah[1], Hassan Abdullah Al-Rizqi[1], Nedhal Al-Tamimi[1], Ammar Maghrabi[2], Yakubu Aminu Dodo[1]

[1]Department of Architectural Engineering, Faculty of Engineering, Najran University, Najran, Kingdom of Saudi Arabia
[2]Interdisciplinary Urban and Engineering Research Department, the Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research, Umm Al-Qura University, Saudi Arabia.

Because educational buildings include a diversity of areas and a wide range of users, thermal comfort is an important design consideration. By taking into account architectural configurations including layout, space orientation, and other passive design components like courtyards, this study tries to evaluate educational facility's thermal comforts. For three months, from August to November 2022, the Najran University College of Engineering was the subject of the research. The present investigation included the assessment of interior factors of the environment, like mean radiant temperatures, relative humidity, air velocity, and air temperature. There are 148 people in the sample total—120 students and 25 staff. Simultaneously, a subjective poll was conducted asking residents to respond to a series of questions about their thermal comfort. Less than 80% of users said that the building was unpleasant in terms of heat, as shown by the ASHRAE-55 findings. The average of TSV was less than PMV's (0.34), signifying a statistically significance differences among the 2, according to the T-test. Additionally, 22.5°C is the computed neutral (comfort) temperature from TSV and 23.5°C from PMV. Along with needless high energy demands, thermal discomfort lowers productivity and may have an indirect effect on learning results.

Keywords: Educational Buildings, Hot and Dry Climate, Mean Radiant Temperatures, Najran, Climate, Passive Design, Thermal Comfort.

1. INTRODUCTION

Major components of designing an ideal environment for learning in educational facilities is thermal comfort, particularly in areas with hot, dry weather. Promoting the health and productivity of educators and students in educational settings requires a thorough thermal comfort understanding [1]. Special focuses to the particular situation of the Najran climatic area, which is well-known for having very hot and dry weather [2]. The mental and physical building health of occupants depends on thermal comfort, a complicated notion impacted by temperature, humidity, air circulation, and individual aspects that must be addressed in educational institutions. Good thermal comfort solutions are especially important for educational buildings in hot and dry regions like Najran, where temperatures may regularly rise beyond 40°C [3].

Situated in the southwest region of Saudi Arabia, Najran endures intense summer temperatures that might negatively affect pupils' ability to concentrate and study. Therefore, it is crucial to comprehend and improve thermal comfort in educational buildings in light of this difficult environment [4]. The objective of this research is to examine the present condition of thermal comfort in educational buildings located in the Najran climatic area [5]. The study will consider several elements such as occupant behavior, HVAC systems, and architectural design. Through evaluating current state of affairs and pinpointing opportunities for improvement, this study hopes to provide insightful information that will guide the creation of comfortable, sustainable learning spaces that are suited to Najran's unique climate difficulties [6]. The results of this study will eventually make it easier to create learning environments that improve the wellbeing and academic performance of teachers and students in the area by offering crucial information to educational institutions, architects, and legislators. Based on the void's purpose, the building's layout has an impact on thermal comfort and some areas are impacted by solar radiation. These issues make the building unpleasant in terms of temperature [7]. Students' academic performance is impacted in comparison to institutions with adequate heating and cooling. The college's HVAC system, direction, solar radiation, space utilization, and the actual number of students in relation to available space all have an impact on thermal comfort.

This research aims to assess the impact of architectural configuration on thermal comfort in educational buildings. The specific objectives are: evaluating several types of spaces in the selected building in terms of achieving acceptable thermal comfort levels that required by international standards. Investigating the impact of space orientation in terms of thermal comfort. Collecting thermal preferences for building users given the current situation for the building.

2. LITERATURE REVIEW

2.1 Thermal Comfort

According to Hansen, thermal comfort occurs when there are no behaviorally driven urges to change the surroundings. According to ASHRAE-55, thermal comfort may also be described as "the state of mind in which satisfaction is expressed with the thermal environment." Environmental and individual factors influence how comfortable it is for building occupants to be heated. The following environmental parameters are measured: air velocity (m/s), relative humidity (%), mean radiant temperature (°C), and interior air temperature (°C). Additionally, personal parameters include metabolic rate (met) and clothing insulation (clo) [1].

Depending on the kind of operation, thermal comfort in buildings is measured using one of two standard indices. An indicator called the Predicted Mean Vote (PMV) is used to measure the temperature of the human body. It is calculated by combining the relative humidity and ambient air temperature [2]. The adaptive model is a kind of linear regression model that establishes a relationship between exterior meteorological or climatological factors and interior design temperatures or allowable temperature ranges [3]. The Predicted Mean Vote (PMV) comfort zone is determined by the degree of physiological stress and heat perception. When it comes to thermal perception, PMV values below -3.5 are classified as very cold due to excessive cold stress, PMV values between -0.5 and 0.5 are classified as comfortable with no thermal stress, and PMV values over 3.5 are classified as extremely hot due to high heat stress [2].

A study comparing thermal comfort in NV mode and AC mode was conducted by [9]. 496 participants and 27 educational institutions in a hot, dry environment in Mexico. People who are 75 years of age or older are given 10 minutes inside the building to complete the questionnaire without having the activity changed. Table 1 displays the comparison in two formats.

Table 1. A comparison of the two ways of thermal comfort (natural ventilation vs air conditioning, or AC vs NV). Adopted from [9]

Preference	AC mode	NV mode
Feeling comfortable	48.1%	59.7%
Feeling cold	44%	11%
Feeling warm	7.9%	29.3%

In Medina, another study on thermal comfort was carried out by [10], who gave questionnaires to 116 students.

Table 2. Summary of indoor/outdoor environment variables.

Parameter	Average	Max.	Min.
Ground floor- Relative Humidity (%)	72.40	77.40	60.80
Ground floor-Indoor Air temperature (°C)	30.30	30.90	29.40
First Floor- Relative Humidity (%)	68.40	74.20	65.00
First Floor- Indoor Air Temperature (°C)	31.40	32.30	29.90
Outdoor Relative Humidity (%)	67.70	73.20	64.80
Outdoor Air Temperature (°C)	31.70	32.30	30.50

Most of responses shows that they agree with the general thermal-condition, as shown by an analysis and comparison of the data with the ASHRAE-55 guidelines. Furthermore, since ASHRAE-55 is less than 80%, it is unpleasant [10].

Additionally, field research on thermal comfort in educational facilities was done. Finding the confounding variables influencing heat perception was the study's goal. The research' findings demonstrated that children's thermal perceptions varied greatly from adults'. When designing, these have to be considered [11]. 240 participants completed a questionnaire created specifically for the research on productivity in class, the outcome is that attention in the classroom is greatly impacted by carbon dioxide and personal characteristics, as well as thermal comfort, which has a significant influence on productivity [12]

A different study attempts to demonstrate how thermal comfort research in school buildings has advanced over the last fifty years. A selection of 93 studies was made using the Scopus database. According to the findings, pupils at all academic levels are more at ease when they are closer to the cooler end of the thermometer. The research also demonstrated how the exterior climate's thermal comfort influences the seasons with natural ventilation. Additionally, the summertime neutral temperatures in the NV seasons are greater. According to a research done on NV/FR classrooms, pupils are more sensitive to temperature fluctuations throughout the summer [13].

2.2 International Standards

When building in hot areas, HVAC systems must be incorporated to control temperature, according to an assessment of national, international, and EU requirements related to thermal environmental comfort for human activities.

2.3 International Organization for Standardization ISO77350-2005

2.3.1 Predicted mean vote (PMV)

The PMV is regarded as an indicator that predicts the mean value of large groups of votes cast by individuals on the 7-point thermal sensation scale, which is based on the body's thermal balance and is shown in Table 3. Notably, thermal balance happens when the body's internal heat production equals the amount of heat lost to the surroundings. Human thermoregulatory mechanisms naturally adjust skin temperature in a typical setting, and sweat to maintain body temperature [14].

Table 3. Seven-point thermal sensation scale.

+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

2.3.2 Predicted Percentage Dissatisfied (PPD)

The PMV is intended to predict the average value related to thermal votes of a large population exposed to comparable settings. Individual votes, however, are not evenly distributed around the observed mean value, and it is important to predict the proportion of people who are likely to feel uneasy in a warm or chilly setting. It is thus indisputable that PPD is considered a measure that serves as the foundation for a quantitative estimate of the proportion of people who experience thermal dissatisfaction due to feeling either too warm or too chilly [15].

2.3.3 ASHARE 55-2013

Four revisions to this standard were made in 1992, 2004, 10, and 2013. The standard serves as a set of requirements for both the people who live in the area under consideration and the environment itself. Any application of the standard must specify the particular environments—if not the whole environment—in which its uses are ideal. Furthermore, each application of the standard has to provide the inhabited areas in which the users have spent at least fifteen minutes. When applying the criterion, one must consider the residents' attire as well as their activities. When persons inhabiting an environment have significant disparities in clothes and physical activity, the standard cannot afford to overlook these differences [16]. While there are many variables that go into determining what constitutes thermal comfort, six are always important and are referred to as fundamental factors; other variables are referred to as secondary ones. Table 1.2 has both major and secondary components mentioned.

2.3.4 Operative temperature

Within certain parameters, such as humidity, metabolic rate, air space, and garment insulation, favorable circumstances may be identified. As a result, the operational temperature range—which offers residents with favorable thermal environmental circumstances—can be used to define favorable conditions. For typical indoor environments, the Graphical Method is used to determine it.

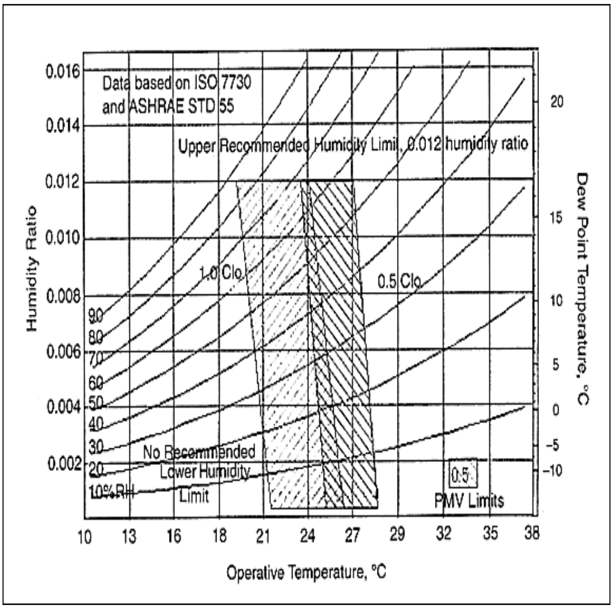

Figure 1. Range of acceptable operating temperatures and humidity for areas that satisfy the requirements given in the following graphical manner (ANSI/ASHRAE 55-2013)

The metabolic rates and clothing levels of the people using these places vary from 1.0 met to 1.3 met and between 0.5 clo and 1.0 clo, respectively, depending on their activity levels. In general, indoor applications are handled using the Computer Model Method. The typical metabolic rates in these areas are between 1.0 met and 2.0 met due to the activity levels of the people; yet, when clothing is worn, the residents' thermal insulation temperatures drop to 1.5 clo or below

2.3.5 Humidity Restrictions

Technologies that are specifically designed to control humidity should be able to maintain humidity ratio below or equal to 0.012 that corresponds to a standard pressure of 1.910 kPa (0.277 psi) or a dew-point temperature of 16.8°C.

2.3.6 European Standard (EN 15251)

All of the specifications listed in EN ISO 7726 should be met by the instrument used to assess the thermal environment. Only in areas where residents habitually spend the majority of their time in the summer and winter—the two main environmental weather conditions—must measurements be taken. Summer measurements are frequently at or above the statistical average, which is why they are considered outside temperatures that last for three months of the year, whereas winter measurements are typically at or below the mean, which is why they are considered outside temperatures and typically last for three months. In order to accurately depict the winter and summer seasons, all measurement parameters should be at least 10 days long. Long-term observations are often taken for interior temperatures, such as room air temperature. It is also simple to estimate suitable room temperatures since interior (room) temperatures may be adjusted for hot or cold surfaces [17-20].

2.3.7 The Chartered Institution of Building Services Engineers (CIBSE)

The PPD will also be used to determine the degree of overheating, as shown in table 5. When a building's ventilation system is inadequately sized or poorly regulated, the building will overheat. Therefore, based on the PMV index, BS EN 15251, as stated by BSI (2007), defined suitable indoor environmental conditions. As a result, factors that contribute to overheating include air speed, humidity, amount of clothes, and occupant activity in addition to temperature. Furthermore, as shown in Table 4, overheating may also be graded according to PPD.

Table 4. Temperature-differentiated weighing factors (or PPD for mechanically heated or cooled buildings)

Description	Temperature (ºC)	Weighing factors	
		WF (Temp.)	WF (PPD)
Cool	20	3	4.7
	21	2	3.1
	22	1	1.9
Neutral	23	0	0
	24	0	0
	25	0	0
	26	0	0
warm	27	1	1.9
	28	2	3.1
	29	3	4.7

2.4 Thermal comfort in educational buildings

Thermal discomfort in school buildings may cause discomfort for both teachers and children. This will most likely be bothersome to the inhabitants, affecting their productivity and performances. According to studies, students at schools were prone to excessive heat stress. Thermal heat-stress is described as the physiological incapacity body to regulate its temperatures at average physiological limits as a consequence of a multitude of variables such as ambient temperature, clothing, behavior, moisture content, and radiation. Thermal conditions must be acceptable to at least 80% of the residents of a building or region (summer warmth is referred to as 26°C to 28°C with relative humidity below 70%). The relevance of thermodynamic comfort is subjective and difficult to quantify. Clothing level, air temperature, humidity, movement of air, radiation of heat, and the rate of metabolism are all environmental and human elements that impact it. It's difficult and pretty subjective. Air temperature, air movement, clothing level, humidity, metabolic rate, and thermal radiation are all environmental and human elements that impact it [21].

A large amount of a student's day is spent in a classroom, and young children are especially susceptible to poor indoor environmental quality. Therefore, a careful investigation of the connection between comfort and classroom attributes is warranted. It is important to design classrooms so that kids can focus and learn more efficiently. Safeguarding thermal comfort within classrooms is crucial for enhancing learners' health and efficiency since the thermal environment has such a big influence on their well-being. However, it should be noted that adults and children do not always perceive heat in the same manner, therefore students' choices about thermal perception are arbitrary. Considering the environment is crucial since it may support co-designing classrooms. In educational institutions, a variety of activities are conducted, which might affect the assessment of thermal comfort, particularly in situations when there is a high metabolic rate. Research has also been done on the impact of thermal comfort on energy efficiency [22-29].

The comfort temperature of individuals may increase with age, while their thermal perception may decrease by almost 0.5 scale units. The age of the occupants may also have an impact on this (on an ASHRAE scale of 7 points) for senior citizens. Depending on their gender and age, they could have different thermal needs. In a situation, you ought to feel comfortable. People's thermal perception in a place may be greatly influenced by personal characteristics, such as cultural background, social conditions, and thermal history [30-33].

Because of this, students at UK higher education institutions may demand differing temperatures inside of classrooms due to their diverse cultural and national origins, as well as their varied thermal experiences. According to Nicol et al. (2012), students in university classrooms often have sufficient flexibility to choose suitable environmental (like opening or shutting windows, utilizing inside shades) or personal (like altering posture, attire, and drinking hot or cold beverages) adaptive behavior. Predicting how instructors and students would react when placed in thermally uncomfortable environments is another factor to take into account when creating appropriate environmental parameters [34-37].

2.5 Comparison of thermal comfort in summer and winter

The purpose of this study is to compare children's summer and winter thermal comfort. We sent out the questionnaire to fourteen schools. According to the data, 70% of the pupils said they felt very heated, and the youngsters expressed discomfort in the colder months due to the heat as opposed to the warmer months. During the summer heat, the overall circumstances in the classrooms were favorable [38, 39].

This research aims to assess thermal comfort throughout the hot season in educational buildings. Forty students from two classes participated in this research. The investigated building has a weather station on its roof, where measurements of the sun's irradiance, air temperature, relative humidity, and barometric pressure were made. The sensors were placed at various spots across the classroom to measure the interior heat condition. Additionally, a questionnaire was given to the pupils. The majority of students reported feeling uncomfortable in the heat, according to the findings; nonetheless, the Thermal Acceptance Vote (TAV) scale identified the maximum permissible temperature range [40-45].

The purpose of this research is to conduct an exploratory investigation in order to highlight the growing unfavourable tendency of utilising air conditioners rather than negative remedies. Study in the humid tropical Atlantic environment of Salvador, Brazil, which has a warm temperature. During the summer, a field survey was carried out once a week at 10:00, 13:00 and 16:00 for eight weeks in a row. Each room had five people questioned, and the class could hold up to thirty people. The measurements of air temperature, relative humidity, surface temperature, and wind speed are the environmental factors that have the greatest impact on the perception of thermal comfort. El Salvador had an average temperature of 28.4 degrees Celsius and a relative humidity of 72%, according to the data. Furthermore, the mean temperature of the rooms assessed was 27 degrees Celsius, with a semester high of 30 degrees Celsius and a lowest temperature of 22.8 degrees Celsius. Every room in the survey had enough windows to allow for natural ventilation [46].

2.6 Factors affecting thermal comfort and the quality of the interior environment

The purpose of the study is to determine if schools should have a training in Sense Lap to enhance the standard of the interior environment. 335 students from seven elementary schools took part in the session. According to workshop data, 27% of the kids felt very warm, 15% felt extremely cold, 5% felt extremely cold in the winter, and 5% felt extremely warm in the summer. The workshop's outcomes demonstrated IEQ issues in the classroom via written language or images, demonstrating children's ability to recognise these issues and their solutions, generate concepts that govern IEQ, and collaborate in the collaborative design of new or modified classrooms. The noise produced by the kids themselves was the main issue. Due of their unfavourable attitudes about it, girls reported greater issues [47].

The purpose of this study is to provide a summary of the field research on thermal comfort in educational buildings that has been done over the last fifty years. The climatic zone, educational stage, and thermal comfort method were used to categorise the investigations. According to those studies, kids spend a significant amount of time in educational facilities, thus it's critical to give them with thermal comfort. Teachers and pupils may get dissatisfied if thermal comfort is not provided. The following is a summary of the findings and suggestions, supported by data from CIBSE and the thermal comfort standards ISO7730, EN15251, and ASHRE55. The investigations also shown that there is a significant variance in the degree of thermal neutrality within the same climatic zone, indicating the necessity of the micro level research. Studies need to be carried out year-round with an increase in the number of respondents since the majority of them were done in a certain environment and with a specific number of users. Ventilation is among the main elements influencing thermal-comforts and the standard of the interior environment, according to studies. She also noted how human adaptability is influenced by both the internal and exterior environment. The fact that pupils gravitate towards cooler settings and are susceptible to warm ones is among the most significant findings [48]

The purpose of this study is to ascertain the typical actions taken by educators to enhance the indoor environment quality (IEQ) in the classroom and how this affects the comfort of the pupils. A questionnaire was given to instructors and students, and the research included 21 primary schools, 1145 kids, and 54 teachers. The findings revealed that 86% of the students found the loudness uncomfortable and 63% found the scent unpleasant [49].

2.7 Factors affecting TSV

The purpose of this study is to identify the variables that most influence TSV throughout the stages of direct relocation and gradual acclimatisation to the new thermal environment. 384 students' responses to the survey were collected over the course of two weeks in university classrooms. The study's findings demonstrated that TSV was impacted by the environments in which it occurred, that students' perceptions of temperature changed significantly from semester to semester, and that the effect of gradual adaptation prevented gender discrimination in TSV [20]. Additionally, the study showed that clothing, altering it, eating food and drink, travelling by car, and using medical equipment did not have a discernible effect on TSV during spatial transition [18].

The objective of this research on classroom thermal comfort was to identify the permissible temperature ranges, neutral temperatures, and preferred temperatures for Australian students. Additionally, the findings were compared to those of adult populations. The research was conducted in the summer of 2013 at nine schools spread throughout three subtropical climate zones, using a mix of naturally ventilated, evaporatively cooled, and air-conditioned classrooms. From elementary (grade) and secondary (high) schools, a total of 2850 questionnaires were collected. It was found that the students' preferred and neutral temperature was around 22.5°C indoors, which is normally cooler than what is expected for adults in the same thermal environment. The kids demonstrated excellent adaptability to variations in indoor temperature, even with a lower-than-expected neutrality; one thermal sensation unit corresponded to an operating temperature of 4°C. Based on the well-established assumption that an ideal range of indoor operating temperatures correlates with class mean thermal sensations of 0.850 to +0.850, the current study offers a midsummer range of 19.5 to 26.6°C for Australian students. According to the findings, children in more equatorial weather districts exhibited stronger thermal adaptation compared to individuals in less equatorial heat regions, and there were significant disparities in heat sensitivity between schools [22].

The aim here was evaluating the thermal-comfort of secondary students in Indonesia's tropical city of Makassar. Data gathered from eight distinct high schools served as the foundation for the study. 48 classrooms were used for the research, which included 1594 students in total. The data include both measured environmental factors and personal information. Students were invited to complete surveys on their degrees of thermal comfort at the same time. The air temperature in the classrooms that were examined was high. The morning and noon room temperatures varied beginning with 28.20◦C to 33.60◦C. Since the room temperature and the radiating temperatures remained comparable, there was little airflow. Relative humidity was the only measure that could match the national requirement for Indonesia. On the basis of STV (sensation of thermal vote) & CTV (comfort thermal vote), a large number of students still report feeling comfortable (−1 to +1). The majority of respondents would have liked a drop in air temperature, even if around 80% of them accepted the current high temperature. In terms of the PMV (predicted mean vote), just roughly twenty-three percent of respondents were expected to feel warm (+1). According to regression analysis, the neutral temperatures for TSV and TCV were, respectively, 29.0 ◦C and 28.5 ◦C [22].

The primary goal of this research is to assess the thermal comfort of inhabitants in N.V. classrooms at a Madurai-based educational institution along with proposing a passive-design technique to alleviate discomforts thermally during summer. The research strategy consists of two main components. In the first stage, the building environment's thermal comfort is evaluated by examining both external and interior components. Field examinations of the building shape, its exterior, orientations, and outdoor areas are done to evaluate external elements. Thermal comfort survey questionnaires were used to measure internal factors by assessing residents' thermal comfort levels in the case study building. The results of the questionnaire survey showed that because of the increased sun radiation from the west-facing windows, over 80% of students situated nearby window openings and walls reported that afternoon time feels further uncomfortable. Some students said that the radiation from the windows prevented them from sitting close to them, even when the windows were closed. Field research was used to forecast indoor heat conditions. The research's physical and subjective assessments revealed that the students were uncomfortable with the temperature in various parts of the case study buildings [23].

The study looked on thermal comfort in classrooms at colleges and high schools. The investigation was carried out between October 15 and April 15, which is the heating season. The continental climate of Turin is typified by hot, humid summers and cold, dry winters. In Turin, Italy, the research was carried out in many classrooms spread over four high school buildings and four university buildings. The basic information, thermal comfort, indoor air quality (IAQ), visual comfort, acoustic comfort, and final synthesis information were the six components that made up the questionnaire. Air temperature, radiant temperature, relative humidity, and air velocity are analyzed to assess the thermal environment. The findings shown that when respondents rate their level of dissatisfaction with the surveys using the thermos sensory scale's (-2, -3) and (3,2) options, there is no correlation between the measurement of PPD and that number. PPD and the unsatisfied voters agreed when they cast a two-plus vote. People liked slightly warmer situations, but they also accepted neutral or hot thermal conditions, and they desired warmth in a little colder environment. People were opposed to a temperature shift since it was said to be a touch warm [24]

The goal of this project is to build air conditioning systems for university classrooms that are both thermally pleasant and energy efficient. This summer research had 92 students, ages 18 to 24, who were enrolled in the architecture department at Hasanuddin University. The air temperature, relative humidity, radiant temperature, and outside air velocity were all measured using devices. The TSV scale was used, and the questionnaire was completed twice. 35% felt chilly, 15% felt normal, and 18% felt freezing, according to the data. For students, 27°C is the neutral conditioning temperature [25].

The purpose of this research is to get a better understanding of schoolchildren's perceptions of thermal comfort and associated behavioral traits. This research included 4866 students—3545 elementary pupils and 1321 secondary students—during the summers of 2012 and 2013. A thermal comfort questionnaire (PMP-PPD) was used. The exterior climate was gathered from the closest weather station, and devices were placed to measure the inside climate. According to the findings, students who were previously enrolled in classes with air conditioning had a higher propensity to favor air-conditioning A.C. for the preservation of the comforts as opposed to those [26] who were housed in classrooms without air conditioning.

The purpose of this study is to assess an educational building's thermal comfort in all weather conditions. The research was carried out for a full week throughout each season at a secondary school in Cyprus. Thirty male and sixty female students each received a questionnaire. Indoor and outdoor sensors are deployed year-round to monitor air temperature and humidity. The sensors utilized are CENTRE 340 Thermo Recorder and Etch RTIO [27].

Table 5. Percentage of PMV-PPD among seasons.

PMV-PPD	summer	winter	Spring	Autumn
Natural	23%	16.67%	53.3%	40%
Hot	43.34%	6.7%	36%	40%
cold	23%	70%	10%	20%

The purpose of this study is to address certain individual elements that impact thermal comfort in October at Coventry University's higher education facilities. The research included 25 classes, 3 buildings, and 1000 students. Nineteen field surveys were carried out in the morning and afternoon in six distinct halls. It considers the average radiation temperature measured at various times of the day, air level and velocity, and interior air temperature [28].

Table 6. Percentage of TSV.

Much colder	5
colder	24
similar	38
warmer	27
Much warmer	7

This research aims to assess interior thermal comfort in hot, dry climates by providing a broad overview of Post Occupancy Evaluation (POE) in higher education facilities. The PMV scale was used to administer the thermal comfort questionnaire throughout the research, which was carried out in three distinct locations and three distinct buildings within the College of Engineering.

3. METHOD USED FOR THIS STUDY

The study combines a reviewed of secondary data from selected peer reviewed research that informed an experiment carried out for three months, from August to November 2022, the Najran University College of Engineering was the subject of the research. The present investigation included the assessment of interior factors of the environment, like mean radiant temperatures, relative humidity, air velocity, and air temperature. There are 148 people in the sample total—120 students and 25 staff. Simultaneously, a subjective poll was conducted asking residents to respond to a series of questions about their thermal comfort.

3.1 Neutral Temperatures

This study was conducted in Harbin university offices and classrooms in order to establish a neutral temperature under the influence of various temperatures, as well as to ascertain the relationship between the indoor thermal environment and thermal adaptation in the winter and spring and to provide a strategy for changing the temperature in indoor places. In the classrooms, 88 questionnaires were gathered in the winter months from the offices, 200 in the winter from 21 courses, and 200 in the spring from 18 classes. Questionnaire: The background survey included questions on gender, age, and duration of stay in the area. In addition, there are activity and clothing checks, and a thermal sense scan. There was just one completion of the questionnaire. Measurements: In the center of the room, at three different heights of 0.1, 0.6, and 1.1 meters, the subjects' surrounding air temperature and velocity were recorded. Findings: In the spring, the average air temperature in the classrooms was 22.8°C, while in the winter, it was around 25.5°C in the offices and classrooms. The relative humidity and air velocity were found to be within the range of 10% to 30% and 0.12 to 0.17 m/s, respectively. Climates may also affect a person's capacity for adaptation. When humans are exposed to a pleasant thermal environment for an extended period of time, neutral thermal comfort levels are about similar to indoor air temperatures [29].

The purpose of this study was to examine how Hong Kong university students adjusted to the air in their classrooms. From August to October of 2015, the study was carried out in mechanically air-conditioned classrooms in Hong Kong. Hong Kong has hot, muggy summers. 982 students took part in the study and answered the questions. There were two sections to the questionnaire; the first asked you to remain in the room and spend 10 minutes understanding the questions. Standard questions about the temperature feeling in response to the room's state were employed in the second section. The measured physical properties of air, temperature, air velocity, and global temperature are all included in the measurements. Throughout the survey, the row was kept in a steady state for more than thirty minutes. A colder thermal environment was the outcome. The findings further demonstrated that PMV and MTSV varied significantly from one another. Additionally, there was a little discrepancy seen between the measured desired degree of comfort (24.85) and the degree of neutral thermal comfort (24.14) [30]

In order to anticipate students' preferred temperature, this research presents novel methods for personality development and thermal comfort models based on student behaviour using PCS chairs. Additionally, an automated solution for the multi-layer classification and thermal preference issues (warmer, colder, no change) of the students is applied in this research. 38 persons took part in the field research, and online questionnaires were completed three times a day. According to the findings, 4 out of 38 voters cast ballots (no change), and the average person's accuracy for comfort with PCS chairs was 68 percent [31].

3.2 Empirical Studies

The empirical findings n summarizes various studies on thermal comfort in educational settings, encompassing different objectives, sample sizes, and findings. In one study comparing AC and NV modes in 27 educational institutes with 496 participants, the majority of students in AC mode felt comfortable, while those in NV mode reported even higher comfort levels. Another study on IEQ improvement strategies involved 21 primary schools, 1145 students, and 54 teachers, revealing concerns about noise (86%) and smell (63%).

In a different study involving 92 students, the goal was to create energy-efficient air conditioning systems for university classes. Meanwhile, a study with 116 students investigated perceptions of thermal comfort and found that respondents generally agreed with their thermal conditions, contrasting with ASHRE 55 building standards. Notably, a study with 4866 students discovered that those in air-conditioned classes had a higher inclination toward choosing air conditioning for comfort.

Several studies explored the impact of thermal comfort on productivity and behavioral traits. One study with 240 participants aimed to understand the effect of local thermal comfort on productivity in university classrooms, emphasizing personal factors and carbon dioxide. Additionally, a comprehensive review of 93 studies over fifty years aimed to track progress in thermal comfort research in educational buildings.

Studies delving into seasonal variations indicated that students generally preferred colder environments, and the neutral temperatures in NV seasons were higher in the summer. Another study comparing children's thermal comfort in summer and winter across 14 schools found discomfort in heat during cold months. These studies collectively contribute insights into factors influencing thermal comfort, ranging from environmental conditions and building designs to individual preferences and adaptation. The varied objectives and sample sizes underscore the complexity of understanding and optimizing thermal comfort in educational settings.

4. RESULT AND DISCUSSIONS

4.1 Data Distributions

The collected data displays the dispersal of TSV at the investigations and the considered PMV. Rendering to ISO-7730:2005, the comfort ranges from $-0.5 \leq PMV \leq +0.5$, then accord it to ASHRAE-55, the comfortable range is $-1 \leq TSV \leq +1$.

Table 7. Thermal acceptability percentage for both subjective and objective measurements.

Thermal Accessibility	Overall	Staff	Student
$-1 \leq TSV \leq +1$	71.72%	15%	56%
$-0.5 \leq PMV \leq +0.5$	68.27%	5.5%	55%

The responses from the customers made it evident that the building is thermally unpleasant according to TSV, as illustrated in Figure 2, with the percentage of thermal comfort (71.72) being less than 80%.

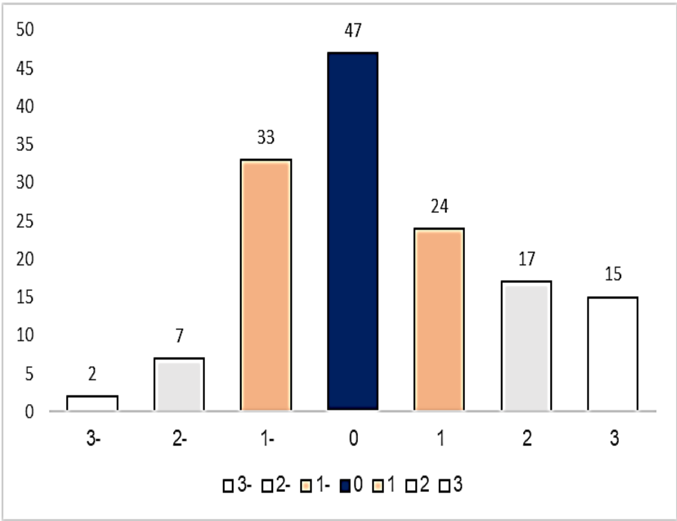

Figure 2. Thermal sensation votes (TSV) distribution.

According to ASHRAE-55, the building is thermally unpleasant, as shown by the PMV findings, which also revealed that the building's thermal comfort rating is 68.27%. However, TPV data revealed that 11% of users prefer a higher temperature, 24% prefer a colder temperature, and 45% of users prefer a somewhat cooler temperature. Additionally, according to TPV data, 16% of users like a temperature that is somewhat hot, as shown in Figure 3.

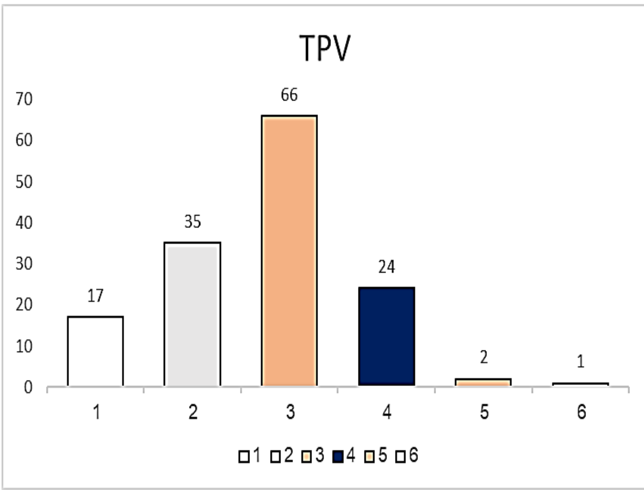

Figure 3. Thermal preference votes (TPV) distribution.

4.2 The relationship between TSV and PMV

For the whole population, Table 8 demonstrates that there is a considerable difference between TSV & PMV. There is a noticeable contrast between the staff and the pupils when comparing them, with the personnel seeming to be more focused. The PMV (mean) for faculty and students is less than the TSV.

Table 8: The results of the two-sample t-test for TSV and PMV for the overall and sub samples:

Subject	TSV (mean)	PMV (mean)	t	p-value
Overall	0.01	0.34	1.65	0.002
Staff	-0.36	-1.09	2.39	0.012
Students	0.49	0.25	1.96	0.025

4.3 Neutral Temperature

The neutral temperature, or the temperature at which TSV or PMV equals zero, was found by the use of linear regression. In the process of pooling TSV and PMV, Top was used as a predictor variable (the regression was derived from 0.13 Top). The results demonstrated that the R2 generated by the TSVs was often too low to be considered a valid liner connection (Figure 4).

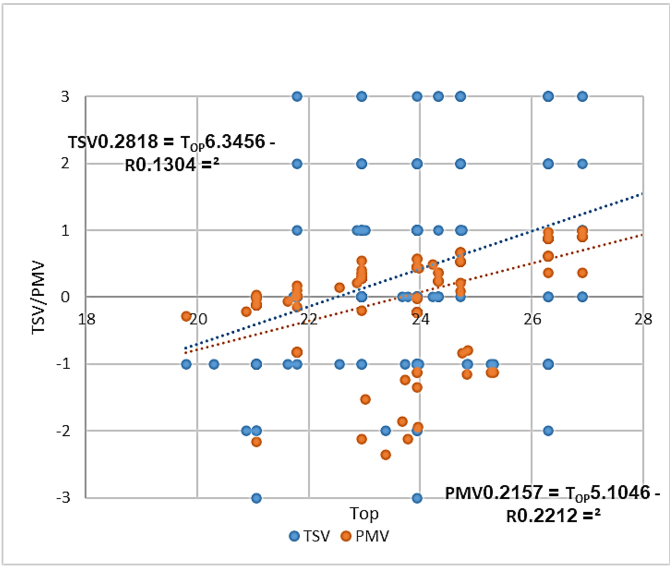

Figure 4. The linear regression between TSV and Top.

Given that the PMV in this study was calculated from the observed physical parameters, one of which being temperature, it is not unexpected that the data fit is better. The neutral temperature might be ascertained as a result. The neutral PMV temperature for Overall is 23.5, for Staff it is 19, and for pupils it is 22.5, as shown in Table (4.3). Additionally, it demonstrates that the TSV's neutral temperature for staff is 25, for students it is 22, and for the whole TSV, it is 22.5. The neutral temperature of Overall PMV is one degree higher than TSV, as shown in Table (9). In comparison to the TSV, the Staff is 6 degrees smaller. It is also evident that the students' neutral temperature for PMV is 0.5 times higher than for TSV.

Table 10. Linear regression results alongside calculated neutral temperature.

Index	sample	a	b	p-value	R^2		T_n
PMV	Overall	5.1046	-0.2157	0.002	0.2212	Sig	23.5
	Staff	3.7957	-0.2007	0.012	0.068	Sig	19
	Student	4.1422	-0.1838	0.0125	0.0197	Sig	22.5
TSV	Overall	6.3456	-0.281	0.002	0.1304	Sig	22.5
	Staff	3.8341	-0.1505	0.012	0.1265	Sig	25
	Student	6.0774	-0.2752	0.025	0.0408	Sig	22

5. CONCLUSION

By taking into account architectural configurations including layout, space orientation, and other passive design components like courtyards, this study tries to assess thermal comfort in educational facilities. The Najran University College of Engineering was the subject of the research. In order to gather data for the research, residents were asked to complete a subjective questionnaire on thermal comfort. The sample size consists of 25 staff members and 120 pupils. The average of TSV was less than PMV's (0.34), indicating a statistically significant difference between the two, according to the T-test. According to ASHRAE-55, the findings indicated that the building is thermally unpleasant.

During this research, a number of limitations were encountered:

(a) We were unable to access many classrooms;

(b) It is likely that the building management system (BMS) is not functioning; some offices and classrooms lack thermostats;

(c) The number of students is significantly less than the capacity of the classrooms; and

(d) There were not enough lecturers to allow us to collect data after 4:00 pm.

Future studies should include the following points:

(i) Measuring in both summer and winter for a subset of classrooms and workplaces;

(ii) Including both genders in the population; and

(iii) Utilizing Design Builder or Energy Plus for thermal modelling in order to calculate the potential for energy savings.

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