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The Evaluation of Thermal Comfort on Primary Schools in Hot-Humid Climates: A Case Study for Antalya

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Abstract
Thermal comfort provides undoubtedly a great contribution to sustainability. Thermal comfort of classrooms has a direct impact on both learning and energy conservation through a careful temperature control. This study is aimed to emphasize economic, environmental sustainability in schools.
Urbanisation and modernisation have led to spend an essential part of people's lives in indoor spaces. Targeted climatic comfort conditions do not change very much despite the fact that significant change of external climatic conditions depending on climate zones and periods during the year. Therefore, this topic has a great importance in terms of keeping at maximum level of expected performance of architectural structure and carrying positive samples to future.
Temperatures that might cause thermal discomfort starts in May for Antalya. After selecting a primary school in Antalya dominated by hot-humid Mediterranean climate conditions, questionnaire prepared according to Fanger's 7-point sensation scale was conducted on 7th and 8th grade students. The questionnaire was implemented on 74 students (41 male and 33 female). At the end of the research, thermal comfort data in primary school classrooms was obtained according to thermal comfort variables such as air temperature, relative humidity, activity level, air speed, clothing choice, gender, age. The level of thermal comfort of the students and thermal environment conditions of the classes was determined.
As a result of obtained data, PMV (predicted mean vote) and PDD (predicted percentage dissatisfied) were identified. According to ASHRAE 55 Standard, examined classrooms were evaluated.

Key Words: Thermal Comfort, Sustainable Schools, Hot-Humid Climates

1. Introduction

Urbanisation and modernisation have led to spend an essential part of people's lives in indoor spaces. In these spaces, factors forming negative or positive effects on users' performance determine the comfort levels of spaces from various perspectives. Thermal comfort is one of the most important factors affecting productivity and efficiency. There is no doubt that thermal comfort of classrooms has a direct impact on both learning and energy conservation through a careful temperature control. It is clear from recent research and research in the past that temperatures in classrooms are important factors in the learning process and improving thermal comfort should be given much priority (Zeiler and Boxem, 2009). The importance of maintaining adequate indoor air quality

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and mostly thermal comfort especially in schools is recognized as being a contributing factor to the learning performance of pupils (Fisk, 2000; Synnefa et al., 2003).

Thermal comfort is a significant factor of the indoor environment, not only because of the comfort sensation that the occupants feel, but also because it is related to the energy consumption of a building, which influences its sustainability (Nicol & Humphreys, 2002).

As Faustman, Silbernagel, Fenske, Burbacher, and Ponce (2000) stated, indoor environments in schools have been of particular public concern since children have greater vulnerability to some environmental pollutants than adults, because they breathe higher volumes of air relative to their body weights and their tissues and organs are actively rowing. It is also worth mentioning that children spend more time in school environment than at home and therefore the environmental conditions of schools are considerably important.

Tanabe and Kimura studied the importance of air movement for thermal comfort under hot-humid conditions. Their study is divided into two parts. In the first part, the effect of air movement on thermal comfort was examined in a naturally ventilated area and was based on previous experimental data. In the second part, the effect of air movement fluctuations on thermal comfort was studied in a forced ventilated area. In both part of their studies, a 3-hour test was performed on 32 male and 32 female participants. It was predicted that clothing insulation was 0.5 clo. Air temperature was determined as 27,9 ^{0}C and 31,5 ^{0}C and relative humidity was 50% and 80%. They analysed the relationship between air velocity, humidity and temperature for optimum thermal comfort (Ng W.S., 1999).

Gennusa researched how shading to be done in the window effects thermal comfort by computer simulation in the study analysing the effects of solar radiation on thermal comfort (Gennusa, et. all, 2007).

Thermal comfort is one of the most important parameters of the indoor quality. According to International ISO Standard 7730, Thermal comfort is defined as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ISO 7730:2005).Six factors are influencing the thermal comfort of humans, four of which are environmental (physical parameters) and two personal factors. The environmental factors are the air temperature, the mean radiant temperature, the air velocity and the air humidity. Personal factors are the metabolic rate of the human and the insulation through clothing.

Environmental Factors:

Ambient air temperature: This is the temperature of the air surrounding the body. It is usually given in degrees Celsius (°C) or degrees Fahrenheit (°F). It affects the dry and humid exchanges as well as the heat transfer coefficient.

Air velocity: It greatly affects convective and evaporative losses. Near the clothed body, the body motion can increase it. A minimum speed of 0.1 m/s always exists, due to a permanent natural air movement everywhere.Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature.

Relative humidity: If water is heated and it evaporates to the surrounding environment, the resulting amount of water in the air will provide humidity. Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of

water vapour that the air can hold at that air temperature. Relative humidity between 40% and 70% does not have a major impact on thermal comfort. In some offices, humidity is usually kept between 40-70% .
Mean radiant temperature: Mean radiant temperature is the uniform surface temperature of a black enclosure with which an individual exchanges the same heat by radiation as the actual environment considered. Thermal radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in an environment. Radiant temperature has a greater influence than air temperature on how we lose or gain heat to the environment. Examples of radiant heat sources include: the sun; fire; electric fires; furnaces; steam rollers; ovens; walls in kilns; cookers; dryers; hot surfaces and machinery, molten metals etc.(Corgnati; Filippi; Viazzo, 2007).
Personal Factors:
Metabolic Rate: The ASHRAE Standard 55 (2010) defines metabolic rate as the level of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface. Metabolic rate is expressed in met units, which are defined as 1 met = 58.2W/m2, which is equalto the energy produced per unit surface area of an average person seated at rest. . Some common values are 0.7 met for sleeping, 1.0 met for a seated and quiet position, 1.2–1.4 met for light activities standing, 2.0 met or more for activities that involve movement, walking, lifting heavy loads or operating machinery.
Clothing Insulation: The amount of thermal insulation worn by a person has a substantial impact on thermal comfort, because it influences the heat loss and consequently the thermal balance. Clothing insulation is expressed in Clo units where 1 Clo corre-sponds to an R-value of 0.88 F ft2h/Btu. Layers of insulating clothing prevent heat loss and can either help keep a person warm or lead to overheating (Givoni,1976; Berger,1993).

2. Research Methodology

Antalya is a Mediterranean coastal city in Turkey and has a hot-humid climate. After determining a primary school in Antalya, classrooms situated in the north and south facade were selected for thermal comfort analyses. Thermal data of the classes was examined in May. The survey was implemented on 74 students (41 male and 33 female). Questions in the survey were prepared in a way that covers Fanger's 7-point thermal sensitivity scale. Also, CBE Thermal Comfort Tool was utilized in the calculation of indoor thermal comfort.

2.1. Thermal Sensation Scale and PMV_PDD Methods

In order to characterize thermal conditions of an indoor space, Fanger (1970) developed a model which is based on the PMV and PPD indicators. Predicted mean vote (PMV) is the average comfort vote, using a seven-point thermal sensation scale from cold (−3) to hot (+3) as it is referred on the ASHRAE 55 Standard (2004, 2010). The PMV zero is the ideal value, representing thermal neutrality. This model was originally developed by collecting data from a large number of surveys on people subjected to different conditions within a climate chamber. Predicted percentage of dissatisfied people PPD is related to the PMV as is defined as an indicator that establishes a quantitative prediction of the thermally dissatisfied people. The model is also based on the simplification that PPD is symmetric around a neutral PMV (Papadopoulos, Oxizidis, & Papandritsas, 2008). The PPD indicator is associated with the PMV using Eq. (1)

$$PPD = 100 - 95 \exp(-0.335\ PMV4 - 0.217\ PMV2) \quad (1)$$

Table 1. Seven-point thermal sensation scale

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

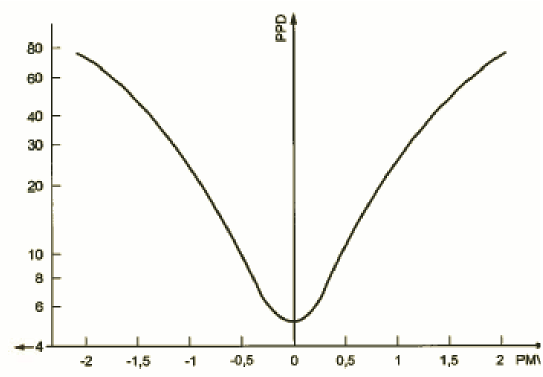

Figure 1. Predicted percentage dissatisfied as a function of predicted mean vote

3. Identification and Evaluation of the School Building

Private Toros Mediterranean School at Konyaaltı district in Antalya was selected for the research. Its distance from the sea is about 700 meters. V-shaped primary school building contains 16 classrooms, 4 music rooms, 3 science labs, 5 painting studios, 2 computer rooms, 1 gym, 1 school cafeteria in total. The school is a 5-storey building. Grade 7th and 8th are in the fourth and fifth floor. 2 classes from the north facade and 2 classes from the south facade were observed. The air conditioning units during the summer months and heating systems during the winter months are used.

Table 2. Characteristics of the selected classes for the study

Class	Facade	The average age of students	Floor	Grade
A	North	13.2	4th	7th
B	North	14.3	5th	8th
C	South	13.4	4th	7th
D	South	14.1	5th	8th

Figure 2. Picture from school outdoor *Figure 3. The corridor of the second floor*

Figure 4. Classes from the south and north facade

3.1. The Evaluation of Classes in terms of Thermal Comfort

3.1.1 Class A

There are 8 female and 10 male students in this class. It has northern front. The average air temperature was recorded 27.5^{0}C for 10 hottest days of May.Students wear their school uniforms and perform their school activities. Relative humidity in the class is 52 %. According to ASHRAE Standard 55-2013, measurements provide 89% user satisfaction and 0.55 PMV value. If the air temperature shows 26^{0}C, dissatisfaction rate will be 5% with -0.01 PMV value.

3.1.2 Class B

There are 9 female and 12 male students in this class. It has northern front. The average air temperature was recorded 27^{0}C for 10 hottest days of May. Students wear their school uniforms and perform their school activities. Relative humidity in the class is 51 %. According to ASHRAE Standard 55-2013, measurements provide 92% user satisfaction and 0.35 PMV value.

3.1.3 Class C

There are 9 female and 7 male students in this class. It has southern front. The air temperature was recorded 29^{0}C in summer period. Students wear their school uniforms and perform their school activities. Relative humidity in the class is 62%. According to ASHRAE Standard 55-2013, measurements provide 64% user satisfaction and 1.22 PMV value. If the air temperature shows 27.1^{0}C, dissatisfaction rate will be 10% with 0.49 PMV value.

3.1.4 Class D

There are 7 female and 12 male students in this class. It has southern front. The air temperature was recorded 28.6^{0}C in summer period. Students wear their school uniforms and perform their school activities. Relative humidity in the class is 59 %. According to ASHRAE Standard 55-2013, measurements provide 72% user satisfaction and 1.04 PMV value. If the air temperature shows 27.1^{0}C, dissatisfaction rate will be 10% with 0.46 PMV value.

3.2. The Number of Students –Thermal Sensitivity Relations

In May,approximately 41.9% of the students have found these classes as uncomfortable while the 58.1% described the same classes as comfortable. 18.9% of female students and 23% of male students are dissatisfied.

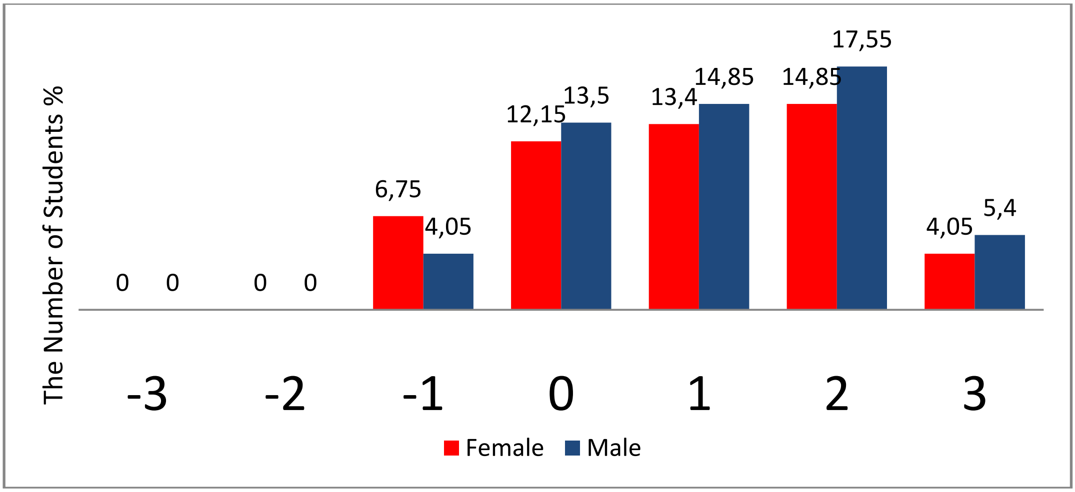

Figure 5. *The Number of Students – Thermal Sensitivity Relations*

In terms of student clothing insulation, girls have a higher clo value than boys. Psychological and personal parameters have a significant impact on evaluating thermal comfort. Furthermore, the investigation also presents differences in the sense of thermal comfort between the two genders. High temperatures affect mainly males, who feel frequently hotter than females. The difference between the two genders occurs mainly because of their different metabolic rate as they have different body surface area.

Table 3. Clothing Insulation Values(clo)

Classes	Girls Avarage clo Value	Boys Avarage clo Value	Classes Avarage clo Value
A	0.56	0.49	0.52
B	0.55	0.47	0.51
C	0.52	0.50	0.51
D	0.51	0.48	0.49
Avarage	0.53	0.48	0.50

40.5 % of students assume that thermal comfort of classrooms is unacceptable according to the survey results.

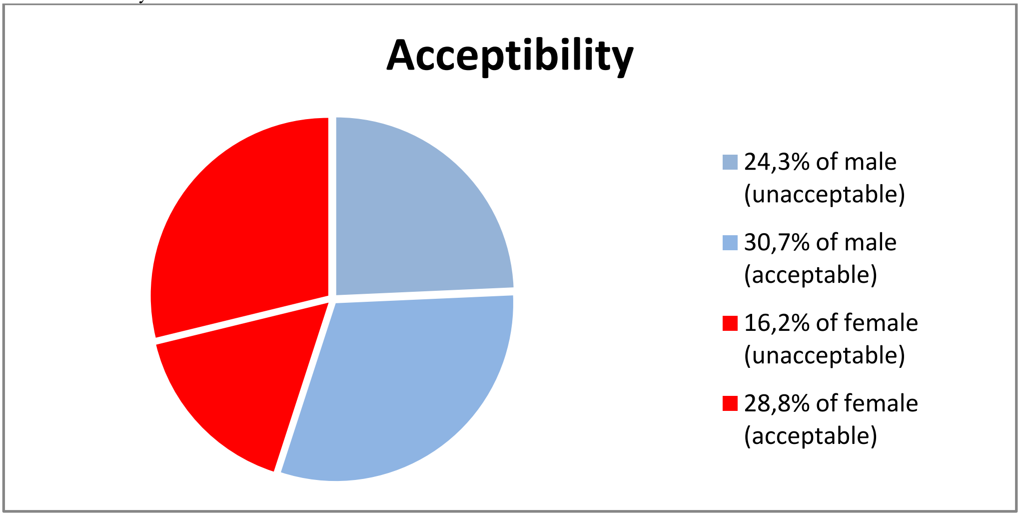

Figure 6. *Acceptability of Thermal Conditions by Students*

3.3 Thermal Comfort- Success Relations

Thermal conditions in classrooms have to be considered carefully mainly because of the high occupant density in classrooms and because of the negative influences that an unsatisfactory thermal environment has on learning and performance (Coley, Greeves, & Saxby, 2007; Fisk,2000). Specifically comfort conditions affect users physically as well as psychologically and consequently they have an impact on the performance of their activities. An interesting review of the first scientific studies about the effects of the thermal quality on the students' performances in classrooms is given in the study of Pepler and Warner (1968).

Holmberg and Wyon observed 9-11 years old children at 20, 27, and 30 ^{0}C. Their performance results show that children felt tired at 27 ^{0}C. There is not a linear relationship between behavioral performance and air temperature. Moreover, they could not suppose that temperature has either a positive or negative impact on learning (Huynh,2001).

Recently, a study based on both a subjective questionnaire survey and objective test scores concluded that learning performance improved with a decrease in the percentage of pupils dissatisfied with the indoor air environment (Mumovicet al., 2009).
Most of the children took into account their psychology within the year while they were interpreting the impact of temperature on their success. They stated that high temperatures and humidity affected their concentration and motivation negatively. High temperatures may cause weariness, tiredness, carelessness, decrease in perception and interpretation, increase in making mistakes. Since Antalya has a mild climate, winter average temperature change between 10 and 18 ^{0}C. Thus, academic performance is not exposed to negative impact of low temperatures in winter. 13,5 % of students stated that air temperature affects the academic achievement.

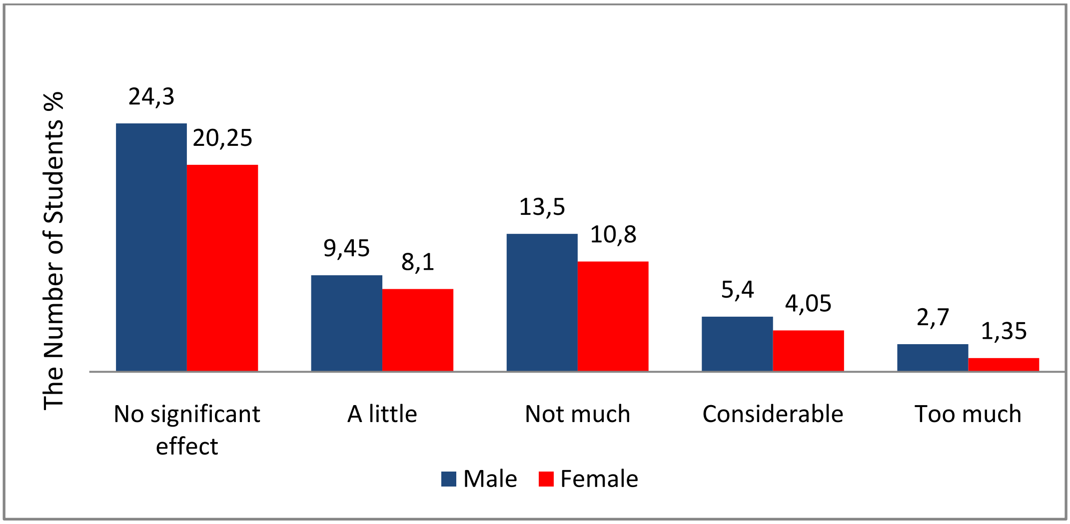

Figure 7. *The Effect of Air Temperature on Lessons*

Conclusion:

The hottest month average in Antalya is 44.6°C and outdoor temperature is almost 76.1 °C in summer (Turkish State Meteorological Service Official Website). Average annual indoor humidity for Antalya is 58-70 % (Kaur, 1994). Through the field measurements it is confirmed that the indoor climatic conditions and specifically air temperature and relative humidity are in many cases unsatisfactory for the occupants. The humidity levels in summer increase so perceived temperature makes the people feel uncomfortable.
This paper discusses the effect of indoor thermal comfort on a primary school under the Mediterranean climate condition in May,2015. If the research results are compared with the ASHRAE Standard 55-2013 values, almost half of students are not satisfied with the thermal comfort of the school in May for Antalya. 40.5 % of students assume that thermal comfort of classrooms is unacceptable. 58.1 % of students described their

classrooms as comfortable according to 7-point sensation scale. Percentage of dissatisfied students is 41.9.

These air temperatures are under central air conditioning. Since there are also a lot of school building which are deprived of air conditioning system, this topic plays a significant role on this hot-humid climate during summer.

In terms of student clothing insulation, girls have a higher clo value than boys.However there is not any considerable difference between them. In the survey, clo value for girls is 0.53 and clo value for boys is 0.48. Although clo value of male students is low, they were affected from high temperatures more than girls.

Classrooms in both south and north facade were evaluated. South facades have higher temperatures. For summer period, north facade could be preferred. Heating insulation to the walls could be applied in order to improve thermal comfort during summer season. Window films and window tint provide energy savings, sun control, improving comfort on southern facade.

This article provides sufficient information about the indoor climatic conditions in school buildings, especially those without insulation.Future studies will focus on the problem solutions in order torestore thermal comfort in school buildings since this has significant impact on the learning performance of pupils. In conclusion the above findings would be useful and appropriate for architects to design climate sensitive education buildings that will provide comfort for the 21st century. Thus, low energy consumption with consideration of students' thermal comfort in hot-humid climate will contribute to economic and environmental sustainability.

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