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A FIELD STUDY ON ADAPTIVE THERMAL COMFORT IN A NATURALLY VENTILATED DESIGN STUDIO CLASS IN THE POST-PANDEMIC PERIOD

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ABSTRACT

Design studios are where design students spend most of their time learning theory and practices. For this reason, thermal comfort conditions in studios are crucial to provide a suitable environment for education. Especially in the post-pandemic period, thermal comfort conditions have become more critical in educational buildings. The present study focuses on the adaptive thermal comfort condition in an architectural design studio in the Mediterranean climate of Izmir/Turkey. The study aims to evaluate the comfort conditions of the students and determine the effect of mask use on thermal sensation in the post-pandemic period. For this purpose, air temperature, relative humidity, and air velocity measurements were collected during the studio hours in the spring semester when the heating and cooling systems were not working. Additionally, a thermal sensation survey was conducted with 42 students. The results showed that the thermal comfort level was within the 90% acceptability limits according to the ASHRAE Standard-55. According to the survey results, the use of masks by the students did not have a significant effect on thermal perception.

1. INTRODUCTION

Along with the COVID-19 pandemic, universities adopted online learning methods over the past two years. The efficiency compared to face-to-face education created great debates in the education community and became an eminent research subject (Ali, 2020; Gillis & Krull, 2020). With the decrease in Covid-19 cases, face-to-face education started again in Turkey at the beginning of 2022. Going back to the classrooms drew attention to the indoor air quality (IAQ) and thermal comfort conditions during the education. As for the faculties of architecture, design studios are where students spend most of their time studying, eating, and even sleeping (Anthony, 1991; Cuff, 1992). It can be assumed that the studios are the main activity spaces in the life of every design student (Oh et al., 2013). Therefore, it is crucial to provide comfortable indoor conditions for these spaces.

Many studies have been carried out on adaptive thermal comfort sensations in education buildings during the pandemic and post-pandemic periods. Alonso et al. (2021) analyzed the effects of the COVID-19 pandemic on thermal comfort and indoor air quality. They compared the conditions before and during the pandemic period in winter. According to their study, thermal comfort was insufficient, and comfort conditions worsened during the pandemic. Shrestha et al. (2021) investigated the adaptive thermal comfort in school buildings in autumn in Nepal. According to this study, at an average temperature of 27°C, most students felt comfortable. Miranda et al. (2022) focused on the ventilation and thermal comfort conditions in classrooms during the pandemic period. When the outside temperature was below 6 °C, the dissatisfaction rates were between 25% - 72%. Conversely, dissatisfaction rates were lower than 10% when the outdoor temperature was above 12°C.

Barbhuiya and Barbhuiya (2013) analyzed thermal comfort and energy consumption in an educational building in the UK. According to their study, thermal comfort levels affected the performance and well-being of occupants, along with their morale. When the comfort levels were not met, occupants' complaints about indoor conditions increased. Singh et al. (2019) reviewed thermal comfort studies in classrooms. According to the results, students at all education stages felt comfortable on the cooler side of the thermal sensation

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scale. There was no consistency between temperature changes and thermal sensation vote. They suggested thermal comfort equations based on the adaptive approach for different school age groups. Taheri Pouresfahani (2021) studied thermal comfort and IAQ in schools before and during COVID-19 by conducting interviews. The results showed that operable windows could significantly impact indoor air quality, health, safety, and student performance. Mohammadi and Nasrabadi (2021) showed the thermal comfort conditions from March to October in the hot and arid climate of Birjand. According to the results, October was the only month when the thermal comfort conditions were met. It was suggested that thermal comfort has dimensions and indices that might be used to regulate energy consumption. López-Pérez et al. (2019) presented thermal comfort conditions in 27 classrooms in Mexico for the cooling period. The study showed that occupants felt more comfortable when natural ventilation was provided than in the air conditioning mode.

Tang et al. (2022) examined the effect of using a face mask on thermal comfort during the COVID-19 period in Guangzhou, China. According to the study, more than 70% of subjects wearing masks said that they were uncomfortable at the university library. Also, subjects wearing masks preferred cooler temperatures. In this study, surveys and interviews were conducted, and the results showed that operable windows could negatively or positively impact indoor air quality, health and safety, and student performance.

In Table 1, thermal comfort field studies in the literature related to the thermal comfort of primary, high school, and university students are summarized. According to this table, the number of students participating in the survey, operative temperature, measured relative humidity value, air velocity, used ventilation system, location, and climate parameters of the building were examined. The comfort temperature varies according to the climate type. These studies are preliminary information and control data for the analysis made for this study, which was carried out in an architectural studio at Izmir Institute of Technology.

***Table 1**: Previous thermal comfort field studies with students*

Study	Space Type	Location	Season	Ventilation mode	T_o (°C)	RH (%)	V_a (m/s)	Clo	Participants
(Yao et al., 2010)	University	Chongqing	Cooling and Heating	Natural ventilation	28-24-14.3	96	0.01-0.53	0.27-0.44-1.42	
(Jung et al., 2011)	University	Korea	Cooling and Heating		24	47.4	0.04	0.72	951
(Teli et al., 2012)	School	England	Heating	Natural ventilation	20-28.8		<0.1	0.35	230
(CAO et al., 2012)	School	Shanghai	All year	Natural ventilation	11.3-30.6				16458
(D. Wang et al., 2017)	School	Northwest China	Heating		13.4-14.3	<60		1.5-1.7	1126
(Fang et al., 2018)	University	Hong Kong	Cooling	Air-conditioning system	24.58 °C			0.42	946
(Udrea et al., 2018)	University	Bucharest		Natural ventilation					765
(Jindal, 2018)	School	India	Tropics	Natural ventilation	27.1	55.5-81.9	0.2-1	0.82	130
(Yang et al., 2018)	School	Sweden	Heating		20-24	20-30	<0.1	0.85	150
(Kim & de Dear, 2018)	School	Australia	Subtropical	Natural ventilation	24.5-24.7			0.42-0.51	4866
(Albatayneh et al., 2019)	University	England	Cooling and Heating	Air-conditioning system	(18 °C–24 °C)				
(Liu et al., 2020)	School	Tianjin	Autumn-Winter		19.51-19.01	41.54-32.20	0.04-0.03	1.1	439
(Kumar et al., 2020)	University	India	Autumn-Winter		18-24	62	0.16	0.95	1332
(Dahlan et al., 2020)	University	Malaya	Tropics		17-35	59-43	0.1-0.7	0.7	10
(Talukdar et al., 2020)	School	Bangladesh	Tropics	Natural ventilation	30.9	78.4	0.8	0.6	286
(Xu et al., 2020)	University	New South Wales							106
(Heracleous & Michael, 2020)	School	Cyprus	Cooling and Heating		30-18	32-58	<0.1	0.5-1	317
(Noda et al., 2020)	School	Brazil	Tropics	Air-conditioning system	26.76	67.6	<0.01	0.44	97
(Korsavi & Montazami, 2020)	School	UK	Cooling and Heating	Natural ventilation	20.02-28.0	43-94	0.05-9.6	0.30-0.74	805
(X. Wang et al., 2021)	University	Xian			17-28	51-76		1.06-0.48	1973
(Shrestha et al., 2021)	School	Nepal	Autumn	Natural ventilation	27	70-83	0.1	0.48	818
(Aparicio-Ruiz et al., 2021)	School	Seville	Cooling		24-27	44		0.3	67
(Guevara et al., 2021)	School	Ecuador	Tropics	Air-conditioning system	18-27.5	51.4-89.3	0.1-0.3	0.85	415

This study presents the results of the fieldwork carried out in Izmir-Turkey in the spring term based on the adaptive thermal comfort approach. In addition to indoor air temperature, relative humidity and air velocity measurements were made in the design studio. A survey is made every hour during the measurements and compared with ASHRAE standards for thermal comfort. In addition, this study aims to understand students' perception of the thermal environment of the classroom, especially with current adaptive thermal comfort guidelines. Additionally, it is aimed to investigate the effect of face masks on thermal sensation perception in a classroom.

2. METHODOLOGY

2.1 Climatic Conditions

The case building is in Urla, İzmir. According to Köppen Climate Classification, İzmir is under the "Csa" section, which is considered hot and temperate in terms of climate features (Rubel & Kottek, 2010). The mean dry-bulb air temperature is 15°C – 38°C on summer days, while on winter days, it changes between -2°C – 16°C. The monthly average relative humidity is 50% all year, while 70% on the winter days (MGM, 2022). The necessary outdoor temperature and relative humidity values were recorded with a data logger during the study period.

2.2 Case Classroom

The case classroom is located on the second floor of the A Block Building of the Faculty of Architecture at İzmir Institute of Technology. There are four user-controlled air conditioner units on the ceiling and no mechanical ventilation system. The classroom locations on the building façade and plan are given in Figure 1.

Figure 1: *Location of the classroom on the plan and façade view of the building*

The classroom has 220 m^2 of floor area with three east-facing windows and two north-facing double pane windows. In Table 2, the dimensions of the walls, windows and doors of the classroom are presented.

Table 2: *Architectural components of the classroom*

Architectural Component	Walls	Windows	Door
East	18.4x3.5 m	3 pieces of 2x2 m	-
West	18.4x3.5 m	-	1 piece of 1.8x2.20
South	12.1x3.5 m	-	-
North	12.1x3.5 m	1 piece of 1x3 m & 1 piece of 2x2 m	-
Area	213.5 m^2	19 m^2	4 m^2

2.3 Data Collection

Indoor field measurements and questionnaire surveys were conducted simultaneously in the classroom. The data collection was carried out when first-year industrial design students participated in a design studio activity from 9:00 am in the morning to 12:00 pm on 19th of April 2022. All data collection materials were placed in the classroom 15 min before the studio started. Before data collection, students were briefly informed of their thermal sensation survey participation that was to be carried out. During the study, the occupants were left free to control the windows, and the AC units were preferred to be kept closed.

2.3.1 Obtaining Thermal Data

Field measurements included seven parameters: outdoor air temperature (T_{out}), indoor air temperature (T_a), indoor relative humidity (RH), and indoor air velocity (V_a). For outdoor environmental parameters, data were obtained by AZ-7798 data logger placed on the outer east wall of the classroom. RH, T_a, and V_a data were recorded by two AZ-7798 data loggers and a Trotec TA300 anemometer placed at three points 1.2 m above the floor level (Figure 2).

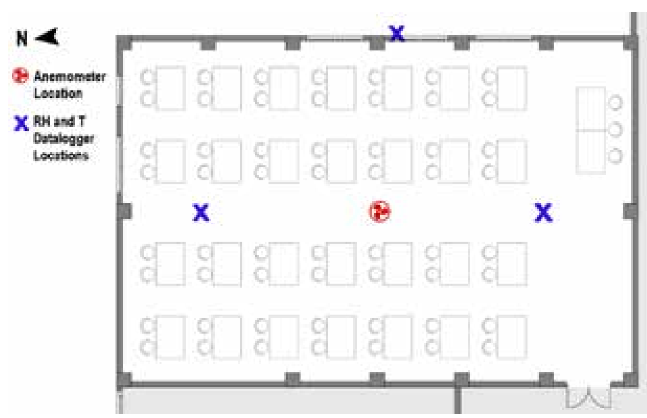

Figure 2: *Locations of the data collecting devices*

All the recorded data were collected at one-minute intervals. Calculation of mean radiant temperature (T_r) and operative temperature (T_o) was done according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 55–2019 Thermal Environmental Conditions for Human Occupancy in Informative - Appendix C – Acceptable Approximation for operative Temperature as in Equations 1 and 2 (ASHRAE, 2019).

$$T_r = 0.99 \times T_a - 0.01 \quad \text{[E.1]}$$

$$T_o = (T_r + T_a)/2 \quad \text{[E.2]}$$

2.3.2 Thermal Sensation Survey

The thermal sensation survey's questions were prepared by the guidance of the ASHRAE-55 "E.1 Point in Time Survey" (ASHRAE, 2019). The question "Are you wearing a face mask?" was included at the beginning of each form. The questionnaires were filled three times during the studio hours, respectively at 10:00 am, 11:00 am, and 12:00 pm. At each hour, students were asked to answer the question, "What is your general thermal sensation?". 42 first-year design students aged between 18 and 21 were included in the study (126 answers for the thermal environment). All 42 students answered all survey questions at each hour. Following the answers of "Describe each item that you are wearing right now?" and "What is your activity level right now?", the mean metabolic rate was determined as 1 met, and the mean clothing insulation as 1 clo complying with the procedures in ASHRAE Handbook Fundamentals: Thermal Comfort (ASHRAE, 2009). The photographs of the design studio during the data collection are given in Figure 3.

Figure 3: *Condition of the design studio during the data collection*

2.4 Thermal Comfort Evaluation

Individual thermal sensation votes (TSV) collected from the survey were valued according to the ASHRAE's seven-point scale, which contains a number representing each response given in Table 3. The effect of wearing a face mask on the thermal sensation was determined by a two-tailed t-test that compared the mean TSVs of the face mask-wearing and not wearing students. The results of the thermal sensation survey were matched with the corresponding mean thermal data, predicted mean vote (PMV), and predicted percentage of dissatisfaction (PPD). PMV and PPD values were calculated using the Center for Built Environment's Thermal Comfort Tool and the adaptive chart that denoted the classroom conditions at 10:00 am, 11:00 am, and 12:00 pm (Tartarini et al., 2020).

Table 3 *ASHRAE seven-point scale for thermal sensation (ASHRAE, 2019)*

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

3. RESULTS AND DISCUSSION

The mean environmental and thermal factors measured during the study were presented in Table 4. During the measurement period, the mean indoor air temperature was stable at around 20.4°C with 51.5% relative humidity and 0.29 $m \cdot s^{-1}$ V_a, while the mean outdoor air temperature was 13.8°C with 67.3% RH. The thermal neutrality ($T_{n,i}$) of the studied classroom is also presented in Table 3 according to the calculation of Auliciems et al. (1998), as it refers to the highest percentage of occupants who can be predicted to vote "neutral (0)" on the ASHRAE seven-point thermal sensation scale (de Dear et al., 2015).

The number of subjective thermal sensation votes corresponding to each thermal sensation category was shown in Table 5, while the means of the comfort values were included in Table 6. TSV According to the thermal sensation survey results, the students' mean thermal sensation vote was -0.29, close to the neutral on the ASHRAE's seven-point scale. The higher temperature and lower relative humidity levels of external conditions resulted in better comfort votes by the occupants, as the significance of these factors was suggested in the previous studies in Malaysia and Nepal (Maarof & Jones, 2019; Shrestha et al., 2021). However, when compared with the mean PMV (-0.65) and PPD (14%) values, it was seen that subjective votes were higher at each measurement period. This result agrees with a similar study conducted in Izmir during winter and summer (Çalış et al., 2017). As the students could adapt themselves by changing clothes and operating the windows, subjective votes were closer to the neutral value than the PMV.

Table 4; *Mean environmental and thermal values*

Hour	T_{out} (°C)	T_a (°C)	T_r (°C)	T_o (°C)	RH (%)	V_a ($m \cdot s^{-1}$)	$T_{n,i}$
10:00	13.5±1.1	20.5±0.1	20.3±0.1	20.4±0.1	51.8±1.3	0.46±0.15	20.4
11:00	13.4±0.5	20.5±0.1	20.3±0.1	20.4±0.1	51.7±0.4	0.22±0.14	20.4
12:00	14.4±0.6	20.2±0.2	20.0±0.2	20.1±0.2	50.9±0.8	0.20±0.14	20.2
Mean	13.8±0.8	20.4±0.2	20.2±0.1	20.3±0.1	51.5±0.8	0.29±0.14	20.3

T_{out}: outdoor air temperature; T_a: indoor air temperature; T_r: mean radiant temperature; T_o: operative temperature; RH: indoor relative humidity; V_a: indoor air velocity; $T_{n,i}$: Thermal neutrality

After the Covid-19 pandemic, the students were free to use face masks according to their preferences in Turkey in 2022. Half of the students preferred to wear face masks during the study, while the others did not. The mean votes of the students wearing face masks were -0.35 and the rest -0.24. According to this result, there was no significant difference between the means of the answers (t: 62, p: 0.55). Therefore, the use of face masks did not affect the thermal sensation in the study.

Table 5: *Number of votes for each thermal sensation category*

Wearing Mask	Hour	cold -3	cool -2	slightly cool -1	neutral 0	slightly warm +1	warm +2	hot +3
No	**10:00**	0	0	10	8	3	0	0
	11:00	0	3	3	11	3	1	0
	12:00	1	1	2	14	3	0	0
	total	1	4	15	33	9	1	0
Yes	**10:00**	0	0	6	11	4	0	0
	11:00	1	3	6	7	3	0	1
	12:00	1	4	5	8	1	2	0
	total	2	7	17	26	8	2	1

Table 6: *Mean subjective thermal comfort values*

Hour	TSV	TSV_{yes}	TSV_{no}	PMV	PPD (%)	Participant Number
10:00	-0.21±0.7	-0.10±0.7	-0.33±0.7	-0.69	15	42
11:00	-0.31±1.2	-0.43±1.3	-0.19±1.0	-0.59	12	42
12:00	-0.36±1.1	-0.52±1.3	-0.19±0.9	-0.66	14	42
Mean	-0.29±0.7	-0.35±0.7	-0.24±0.7	-0.65	14	42

TSV: Thermal sensation vote; TSV_{yes}: Thermal sensation vote for students with face mask; TSV_{no}: Thermal sensation vote for students without face mask; PMV: Predicted mean vote; PPD: Predicted percentage of dissatisfied

Adaptation crucially influences thermal comfort sensation, as shown in the previous study in Malaysia and Japan (Zaki et al., 2017). There was no heating or cooling system in operation during the study, and the natural ventilation was under the occupants' control. The students were free to adapt to the thermal environment by adjusting clothes and drinking beverages. Thus, the result of the thermal conditions during the three measurement periods of the study fell within the 90% acceptability limits according to the ASHRAE Standard-55 (ASHRAE, 2019). The adaptive chart denoting the measurement periods of the study is shown in Figure 4.

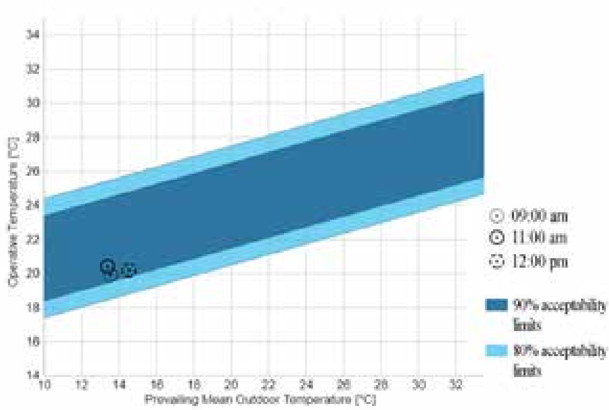

Figure 4*: Adaptive chart that shows the acceptability limits with conditions indicated corresponding to the survey periods*

The study was limited to one design studio class and three hours of the data collection period due to the conditions of post-pandemic hybrid (distance and face-to-face) education. Similarly, other studies on thermal comfort were conducted using a brief period of data. Martinez-Molina et al. (2022) reported the correlations between human thermal sensation votes and indoor environmental conditions in a historic religious building based on the measurements between 12:00 and 13:30 pm, which corresponded to the visiting hours. Papazoglou et al. (2019) investigated thermal comfort perception in a non-air-conditioned school building using thermal sensation survey results, air velocity, and temperature measurements during a 1.5 hours period. Harčárová and Vilčeková (2022) evaluated the thermal comfort and indoor air quality of four office spaces from two buildings consisting of an hour period of measurements from each. Considering these studies from the literature, despite the brief measurement period, the effect of mask use and behavioral adaptability on thermal sensation during a design studio class reported in the present study contributed to the thermal comfort study area.

4. CONCLUSION

In this study, thermal comfort conditions in a design studio classroom in İzmir were investigated. The study included three hours of measurements and thermal sensation surveys with 42 students in the spring semester in the post-pandemic period. The results showed that the students' sensation votes were higher than the PMV values, as the occupants could adapt to the thermal environment by window control, adjusting clothes, and drinking beverages.

As a reference to the post-pandemic period, half of the students preferred to use face masks during studio hours. According to the results, there was no significant difference in the thermal sensation of the students using a face mask and the rest. As the overall evaluation, the thermal comfort conditions of the design studio fell within the 90% acceptability limits according to the ASHRAE Standard-55. The study was limited to a spring day, without the occupants' demand for cooling or heating. Further studies are needed to show the thermal comfort conditions during the classes in the winter and summer conditions.

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