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Determination of the indoor air quality and occupancy satisfaction in architecture studios during model making process

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Keywords

Architecture studio; Model making; Indoor air quality; Thermal comfort; Occupancy satisfaction; Physical symptoms

Abstract

In this study, measurements were performed to determine the indoor air quality and thermal comfort, evaluated to ASHRAE standard during the model making process of the students in the studios where architectural education was given, and whether the low indoor air quality obtained had an effect on the health of the students was determined by the survey method. As a result of the measurements, it was determined that the size of the studio space was largely effective in maintaining the indoor air quality for a long time, and although the natural ventilation continued uninterrupted during the model making, the indoor quality in the studios reached the values that would threaten the health of the students. In addition, it was determined that female students were more disturbed by the low indoor quality than male students.

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Highlights

- In the design of model studios, appropriate space and opening window sizes are important in ensuring indoor air quality.
- The materials used in model making cause high levels of emissions, where even natural ventilation is insufficient.
- Significant physical symptoms were observed in the students due to the emissions released by the model materials.

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Maket yapımı esnasında mimarlık stüdyolarının iç mekân hava kalitesinin ve kullanıcı memnuniyetinin belirlenmesi

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Öz

Bu çalışmada, mimarlık eğitiminin verildiği stüdyolarda öğrencilerin maket yapımı sırasında iç hava kalitesi ve ısıl konforu üzerine ölçümler yapılmış, ASHRAE standardına göre değerlendirilmiş ve elde edilen düşük iç hava kalitesinin öğrencilerin sağlığını etkileyebilecek düzeyde etkisinin olup olmadığı anket yöntemi ile belirlenmiştir. Yapılan ölçümler sonucunda, stüdyo büyüklüğünün iç mekân hava kalitesinin uzun süre korunmasında büyük oranda etkili olduğu, maket yapımı sırasında doğal havalandırmanın kesintisiz devam etmesine rağmen stüdyolarda iç mekân kirleticilerinin öğrencilerin sağlığını tehdit edecek değerlere ulaştığı tespit edilmiştir. Ayrıca kız öğrencilerin erkek öğrencilere göre iç mekân kalitesinin düşük olmasından daha fazla rahatsız oldukları belirlenmiştir.

Öne Çıkanlar

- Maket stüdyolarının tasarımında uygun mekân ve açılır pencere boyutları iç mekân hava kalitesinin sağlanmasında önemlidir.
- Maket yapımında kullanılan materyaller doğal havalandırmanın dahi yetersiz kaldığı yüksek oranda emisyona neden olur.
- Öğrencilerde maket materyallerinin saldığı emisyonlardan dolayı belirgin fiziksel semptomlara rastlanmıştır.

Anahtar Sözcükler

Mimarlık stüdyosu; Maket yapımı; İç mekan hava kalitesi; Isıl konfor; Kullanıcı memnuniyeti; Fiziksel belirtiler

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INTRODUCTION

Learning is a process that produces a permanent behavior change. To sustain this process in a quality way, physical, spatial, social, and psychological comfort conditions such as thermal, visual, and acoustic comfort, as well as the air quality, must be ensured in the learning space. Academic success declines in educational spaces with inadequate comfort conditions (Annesi-Maesano et al., 2013; Wargocki and Wyon, 2013, 2017). Indoor air quality (IAQ) plays an important role in learning success (Bakó-Biró et al., 2012). Many scientific studies have proven that IAQ has a direct impact on students' performance of the study and thus influences academic success (Bogdanovica et al., 2020; Gilliland et al., 2001; Mendell and Heath, 2005; Mohai et al., 2011; Shendell et al., 2004; Stabile et al., 2017). Classroom air quality is associated with various diseases such as asthma, rhinitis, and rhinoconjunctivitis (Fsadni & Montefort, 2013; Madureira et al., 2015). One of the main objectives of architectural education, which includes concepts from many different disciplines and is versatile, is to establish the link between theory, research, and practice (Djabarouti and O'Flaherty, 2019), and classrooms and studios designed accordingly are used in the educational process. Architectural studios are settings where models are made to implement drawings and learning by doing, and verbal and visual information transfers are done as a requirement of architectural education. In this sense, it is necessary to give great importance to the internal comfort conditions during the design phase of these places where several functions are realized. The courses in which learning by doing/practicing takes place in architectural education are design and construction (or construction knowledge) courses. Even though verbal and visual information is passed on to the student at a high level, the student's experience of the process through making models ensures that the learning is permanent and that he/she can anticipate the problems he/she may encounter in practice (Düzenli et al., 2017; Elias-Özkan and Hadia, 2015). For this reason, the process of learning with models is an integral part of architectural education (Elias-Özkan and Hadia, 2015) and it takes place together with the act of drawing in studios. During model making processes in studios, significant changes in indoor air quality can occur, which can also be perceived sensorially. Because of the deterioration of indoor air quality during model-making activities, which can last 7-8 hours or more in architectural education, students experience symptoms such as fatigue, headaches, itchy nose, and sore throat at the end of the day, and due to these, a decrease in their performance and productivity may occur. For this reason, designs of these spaces are done taking into account sufficient windows to ensure thermal and visual comfort and air quality (Bostancı Başkan and Şerefhanoğlu Sözen, 2006; Musa et al., 2012a, Nasir et al., 2011), design and use skills, and social and psychological needs. Openings and ventilation rates (Turanjanin et al., 2014) and the choice of the right and healthy material (Niu and Burnett, 2001) are also important.

It is possible to group the factors affecting the air quality of studio spaces where architectural education takes place as indoor and outdoor factors. Indoor factors are pollutants originating from inside the space, such as building materials and paints used in the space (Gao et al., 2018; Jovanovi'c et al., 2014; Liang et al., 2021). External factors, on the other hand, can be defined as the pollutants that users bring into the room and that reduce the indoor air quality together with materials used in the room. Materials used in model making process (Mishra et al., 2015) along with the internal factors caused by the wrong choice of building materials in architectural studios reduce the air quality of the space as external pollutants. Volatile Organic Compounds (VOCs) released from stationery materials such as superglue, wooden sticks, various types of paper and cardboard used in modeling (Destaillats et al., 2008; Kuśtrowski et al., 2018; Mishra et al., 2015; Pegas et al., 2011; Raysoni et al., 2017; Zhang et al., 2006), and particulate matter can affect air quality in the studio. For this reason, it can be said that the architectural studios serving different work styles are at higher risk in terms of indoor air quality. It is imperative to provide effective natural ventilation in these spaces, which must also be supported by active ventilation systems in case of insufficient weather conditions. In this context, it is important to study the indoor air quality of architectural studios to determine the amount and type of ventilation required for architectural education studios. The purpose of this study was to determine the indoor air quality of the classroom before and during model making in architectural studios and to determine student satisfaction with indoor air quality before and after model making.

Regarding the indoor environment comfort (IEQ) of architecture studios, Musa et al. focused on lighting and temperature in UKM architecture studio spaces to achieve better IEQ (Musa et al. 2012a, 2012b). Nasir et al. (2011) discussed aspects of considering IEQ in creating a conducive learning environment. However, the literature review has shown that there is no study investigating the indoor air quality of architectural studios. Therefore, this study has the distinction of being the first study to determine the indoor air quality during the model making process in architecture studios. The study inspires architects and designers in the design of architecture schools and emphasizes that indoor air quality is an important parameter in ensuring student comfort.

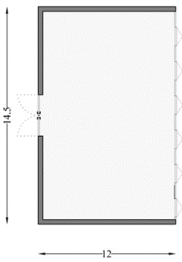
MATERIALS AND METHODS

Studio description

This study was conducted in Safranbolu, Turkey, which has a humid subtropical (Cfa) climate with cool winters and warm summers based on the Köppen-Geiger climate classification (MGM, 2016). It was carried out in a building of the architecture department located in a low-traffic area in the northern suburb of Safranbolu (Figure 1-a, Figure1-b). Two architecture studios were chosen as the study area (their characteristics can be seen in Table 1). The studios were naturally ventilated with the help of operable windows. The wind-rose analysis, created according to the location and direction of the studios, is provided in the Figure 2-a, Figure 2-b. Wall heating with radiator was used in the studios during the survey periods. Aerated concrete block wall construction and double glazed windows with aluminum frames had been used in the architecture department building.

Figure 1 - a. Location of the building b. Surveyed studios.

Table 1 - Studio properties.

Studio	Plan	Area	Windows	Occupancy	Elevation	Volume	Volume/ Number of people
Architecture Studio I		261m²	13 windows (80*120) in two side curtainwall	45	Southeast	730.8 m³	16.24
Architecture Studio II		174m²	6 windows (80*120) in one side curtainwall	33	Northwest	487.2 m³	14.7

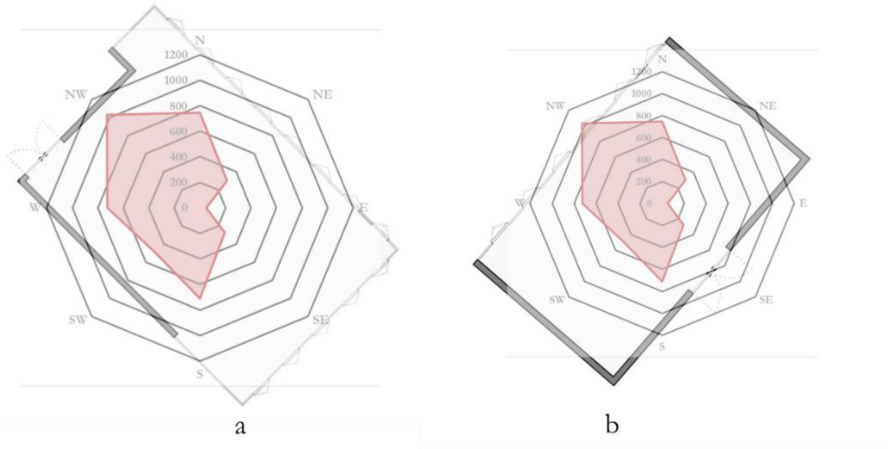


Figure 2 - a. Architecture studio I wind-rose scheme b. Architecture studio II wind-rose scheme.

On-site measurement

Indoor air quality measurements (temperature, relative humidity, CO_2 concentration and TVOCs, $PM_{0.3}$, $PM_{2.5}$, and PM_{10}) have been performed in two architectural studio locations with a difference in direction in a similar ratio of volume/number of people within the scope of the study. Measurements have been taken for four days covering model construction in both studios to increase calibration in measurement results, and these measurements have been averaged for each studio. Given that the type of material used during model construction and the number of users used at similar levels, measurements in each studio for two days were sufficient. According to the EPA Air Sensors Placement and Installation Guide, 3 different points of air circulation, which are not available in ventilation circulation, are uniformly distributed throughout the site, and sensors are placed at 1.5 meters (breathing level) above these 3 different points, which are determined by the same manual (Figure 3). In the manual, measuring periods can be determined, depending on the nature of the instruments being measured and the total time, for at least 15 minutes. According to this article, the measurement results were obtained from the devices during 30 minutes, taking into account the properties of the devices and the nature of the pollutants. The initial measurements, which were measured while the studio was empty, continued until the model making process was completed (the environment of the studios during the model making process is given in Figure 4). However, measurements were interrupted during the students' lunch break (between 12:15-13:30) and the studio was ventilated by opening the windows for 75 minutes. Doors and windows were kept closed during the measurements. When indoor air quality reached alarming levels (TVOCs: 9.99 ppm), windows were opened and measurements continued. Windows were opened at 15:00 for Studio I and at 14:15 for Studio II. Since Studio II had a smaller volume, it took less time for the indoor air quality to reach alarming levels. The reason for continuing the measurements after the windows were opened was to determine the effect of natural ventilation on the indoor air quality of the room and whether it was sufficient. There is no mechanical ventilation system in both studios. The device specifications are summarized in Table 2. As can be seen in Table 3, the temperature, relative humidity, and CO_2 concentration values were evaluated based on the threshold limit values (TSVs) established by the ASHRAE standard, while the TVOCs, $PM_{0.3}$, $PM_{2.5}$, and PM_{10} values were evaluated based on the limit values established by the EXTECH. In the previous literature studies, there are indoor air quality studies with a small number of environments, but with effective results (Stabile et al., 2017, Gao et al., 2014).

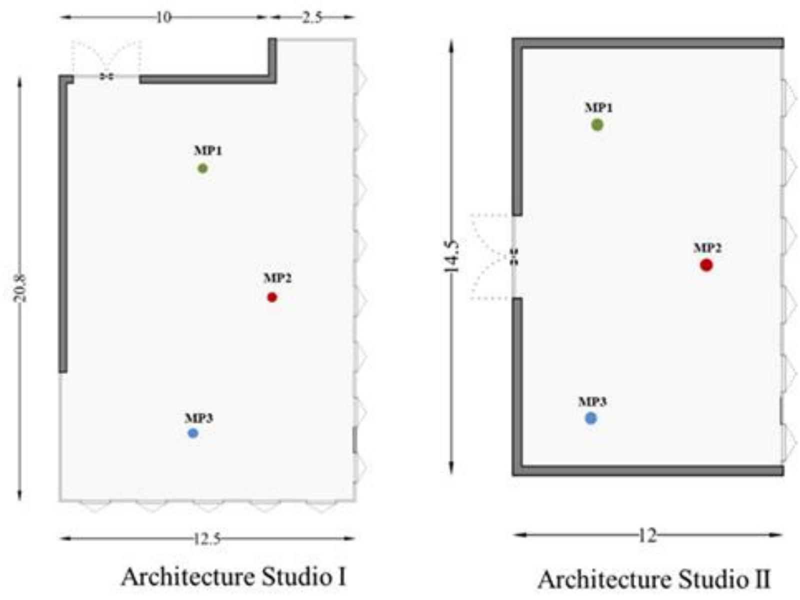


Figure 3 - Measurement points in studios.

Table 2 - Measuring devices and features.

Probe/sensor Parameter	Measuring range	Resolution	Accuracy	Channels
Extech CO250				
CO_2	0-5000 ppm	1 ppm		
Temperature	-10 to 60°C (14 to 140°F)	0.1°F/°C		
Relative Humidity	0.0 to 99.9%	0.1 %		
Extech VFM200				
VOCs	0.0 to 9.99 ppm (ppm)	0.01 ppm	±5%	
Extech VPC300				
PM 0.3, 2.5, 10				0.3, 0.5, 1.0, 2.5, 5.0, 10 µm

Table 3 - The threshold limit value for the parameters.

Parameters	ASHRAE	Parameters	EXTECH
Temperature (°C)	22.5-25.5	$PM_{0.3}$ (µm)	100000
Humidity (%)	30-60	$PM_{2.5}$ (µm)	545
CO_2 (ppm)	1000	PM_{10} (µm)	68
TVOCs (ppm)	2		

Figure 4 - Environment of the architecture studios during model building.

Questionnaire Survey

A total of 45 and 33 subjective responses to the questionnaires were combined in Studio I and Studio II, respectively. As a fieldwork procedure, measurements of the physical variables of the classroom were combined with the subjective survey that recorded students' perceptions of the immediate thermal environment to understand their comfort and thermal conditions in the classroom. To determine the impact of pollutants occurring during the model making process on indoor comfort, students were asked the same questions before and after model making, and the responses were compared. Some items of the survey included thermal sensation vote (TSV) and indoor air quality vote, which were prepared by using the ASHRAE seven-point scale (ASHRAE 55, 2017). In addition, users were asked if they experienced one or more of the sick building syndrome symptoms, such as headaches, fatigue, breathing difficulties, and nasal congestion, as a function of indoor air quality.

RESULTS

Results of spot measurements

Table 4 presents descriptive statistics related to the thermal environment and indoor air quality during model making hours (10:00-17:30) for 4 days. The average temperature and relative humidity for each studio during the measurement period (i.e., 10:00 a.m. to 5:00 p.m. over 4 days of sampling) are shown in Table 4. Studios were sampled on for 4 days, with an average indoor temperature of 18.7°C and an outdoor temperature of 2.3°C. The average indoor relative humidity was 32% and the outdoor relative humidity was 56%. The prevailing wind direction was South-Southeast, which means the wind direction was from the street to the architectural building. During the model making process, high CO_2 and TVOCs concentrations were detected in both studios on 4 separate days. During the measurements, the windows were opened so as not to endanger the health of the students when the amount of TVOCs in the indoor space exceeded the maximum value that the instrument could measure. However, acceptable indoor TVOC levels could not be achieved until the model making process was completed. During all-day measurements, Mean TVOCs were determined as 6.06 ppm for Studio I, while it was determined as 6.67 ppm for Studio

II, which had a smaller volume. The mean CO_2 concentration for Studio I was 789.5, and 950.1 ppm for Studio II. The fact that the TVOCs levels are above the allowed levels even though the windows were opened after a certain period of time during the measurements poses a risk to the health of the students. As a result, it was found that the mean PM levels were within the acceptable levels. The mean $PM_{0.3}$ $PM_{2.5}$ and PM_{10} values were 36072, 183 and 22.5 and 39819, 198 and 22.2 for Studio I and Studio II, respectively.

Temperature and humidity

The temperature and humidity values in the architecture studios were measured before the students entered the studio and were found to be 17 ℃ and 30.3%, respectively. After the measurements started, the temperature in both studios increased until noon due to the number of students and their activities, while it decreased during the lunch break because the students left the studio and the doors and windows were opened. The temperature values obtained during the measurements in the studios remained between the values recommended by ASHRAE until the windows were opened (between 10:30 and 12:00) and decreased below the recommended values after the windows were opened (Figure 5). This situation can be interpreted as the fact that natural ventilation, which is continuous in the winter in model studios, may lead to a reduction in thermal comfort in classrooms. Whereas the relative humidity in Studio II was within the recommended values, it remained below the recommended values in studio I throughout the measurements. It can be said that this situation can cause students to experience some symptoms such as dryness of throat and nose and respiratory problems.

Table 4 - Spot measurement results for studios.

Studios	Parameters	Maximum	Minimum	Mean	SD
Studio I	Temperature (°C)	24.1	17.7	21	7.8
	Relative Humidity (%)	30.8	26.4	28.6	6.4
	CO_2 (ppm)	1114.5	492	789.5	419.2
	TVOCs (ppm)	9.99	1.64	6.06	2.5
	$PM_{0.3}$	54,389	23,429	36,072	8,385.8
	$PM_{2.5}$	271	126	183	37.1
	PM_{10}	42	13	22.5	7.2
Studio II	Temperature (°C)	23	13.7	19.7	5.75
	Relative Humidity (%)	42	31.8	35.4	6.2
	CO_2 (ppm)	1554	414.5	950.1	402.5
	TVOCs (ppm)	9.99	1.67	6.67	2.79
	$PM_{0.3}$	55,616	19,880	39,819	1,2052.4
	$PM_{2.5}$	312	105	198	68.3
	PM_{10}	40	10	22.2	6.6
Outdoor (Mean for 4 days)	Temperature (°C)			2.3	
	Relative Humidity (%)			56	
	CO_2 (ppm)			406	
	TVOCs (ppm)			1.05	
	$PM_{0.3}$			35,289	
	$PM_{2.5}$			372	
	PM_{10}			58	

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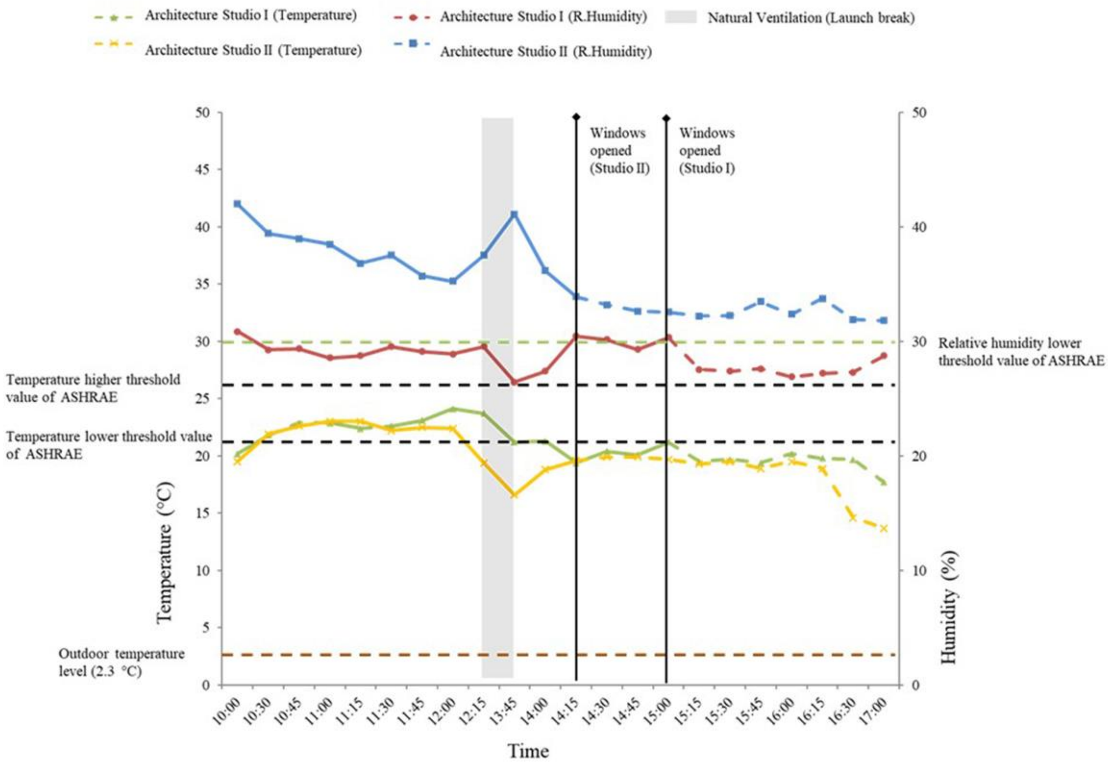

Figure 5 - Thermal measurements in studios.

Temperature-based thermal comfort and humidity values in Studio I and II were determined using the CBE Thermal Comfort Tool in accordance with ASHRAE 55-2020, EN -16798. For Studio I and II, the thermal comfort with closed windows was neutral (PMV: -0.31, PPD: 7% and PMV: -0.35, PPD: 8%, respectively). When the maximum value that the device could measure was observed during the TVOCs measurements, it was seen that the thermal comfort changed from neutral to slightly cool (PMV: -0.56, PPD: 12% and PMV: -0.67, PPD: 14% for Studio I and II, respectively) due to the low outdoor temperature when the windows were open (Figure 6 & Figure 7). When both studios were evaluated in terms of thermal comfort, it was found that the dissatisfaction rate per person was higher in the studio II when the windows were open.

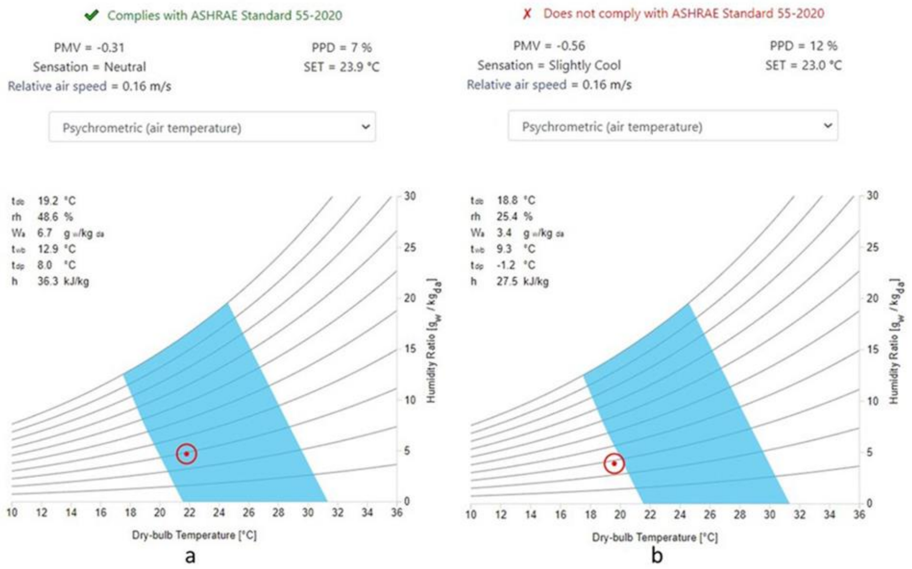

Figure 6 - a. Thermal comfort when windows were closed in Studio I b. Thermal comfort when windows were open in Studio I (CBE Thermal Comfort Tool ASHRAE-55, EN-16798).

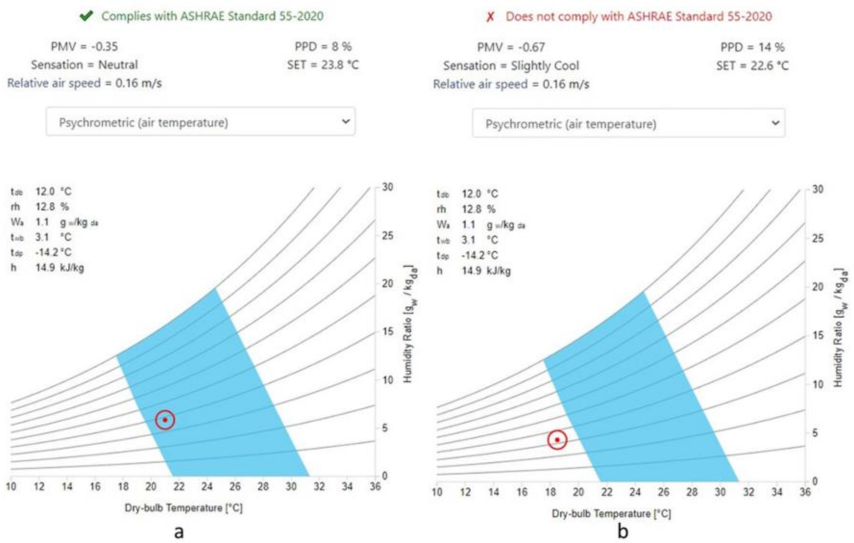

Figure 7 - a. Thermal comfort when windows were closed in Studio II b. Thermal comfort when windows were open in Studio II (CBE Thermal Comfort Tool ASHRAE-55 EN-16798).

CO_2 concentration

In Studio I and II, the CO_2 concentration increased as a function of time, and this increase was faster and higher although the number of subjects in Studio II was smaller than in Studio I. This is because the volume of Studio I (730.8 m^3) and accordingly the amount of fresh air is higher than in Studio II (487.2 m^3) (Franco et al., 2019). As can be seen in Figure 8, the limit value (1000 ppm) was reached 45 minutes after the start of model making in Studio I, while this situation was observed after 30 minutes in Studio II. The reason for the high CO_2 concentration observed in a short period of time might be that students showed both cognitive and physical efforts during the model making. That is, the human CO_2 exhalation is often correlated with metabolic rate, and this is also related to the activity in question (Persily, 1997). The CO_2 concentration, which decreased when the windows were opened at noon, reached the limit of 1000 ppm within 15 minutes in studio II. This result shows that insufficient room volume and insufficient amount of fresh air is a major problem for indoor air quality (Franco et al., 2019; Simanic et al., 2019). Although the CO_2 concentration comes to an acceptable level when the windows are open in the studio, this does not seem possible especially in winter since it causes a reduction in thermal comfort. As can be seen in Figures 5-7, the temperature values dropped below the comfort limits from the moment the windows were opened. Therefore, it is recommended to install a mechanical ventilation system in studios with a high number of users. High CO_2 concentrations detected in the environment may lead to a decrease in student productivity and cause symptoms such as fatigue, dizziness, and headaches (Fernandez-Agüera et al., 2019; Myhrvold et al., 1996; Satish et al., 2012).

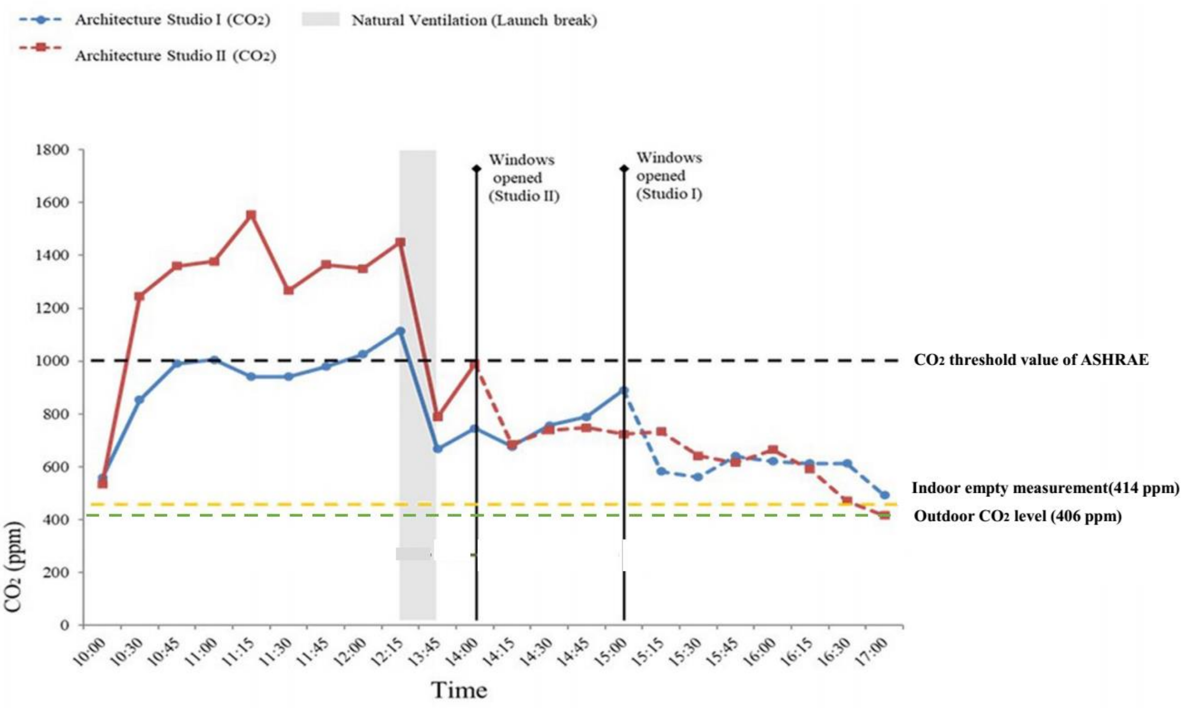

Figure 8 - CO2 concentrations in studios.

TVOCs

When the TVOCs concentrations for both studios were examined, it was observed that the TVOCs concentration in the environment exceeded the limits in about 15 minutes after the start of the model making process in studio I, while the value was above the limit in studio II from the moment of the delivery of materials for model-making due to the smaller space (Figure 9). It is believed that this increase is due to the stationery and superglue used during model making (Kuśtrowski et al., 2018; Madureira et al., 2015; Raysoni et al., 2017). During the model making process, a very high concentration (9.74 ppm) was observed in the middle of the day (12:00 h) in both studios. These levels, which can be described as 5 times the limit value, can cause diseases such as low lung function, asthma, and bronchitis in students (Mother-Maesano et al., 2013; WHO, 2010). Although the levels decreased with natural ventilation lasting 1.5 hours at noon, they did not fall below the limits. It was also found that the natural ventilation should be higher for Studio I because the blow-out time of the polluted air was prolonged due to the large volume. The TVOCs concentrations were 4.81 ppm for Studio I and 3.42 ppm for II at the time when students continue to build models after lunch. These levels, measured after natural ventilation, are in a hazardous range for student health. Depending on the room sizes, the time when the instruments reached the 10 pmm limit, which is the maximum value that the instruments can measure in a studio environment, was 15:00 for Studio I and 14:15 for Studio II. Therefore, it can be said that the small-volume studio loses indoor air quality in a shorter time during the model-making process (Franco et al., 2019).

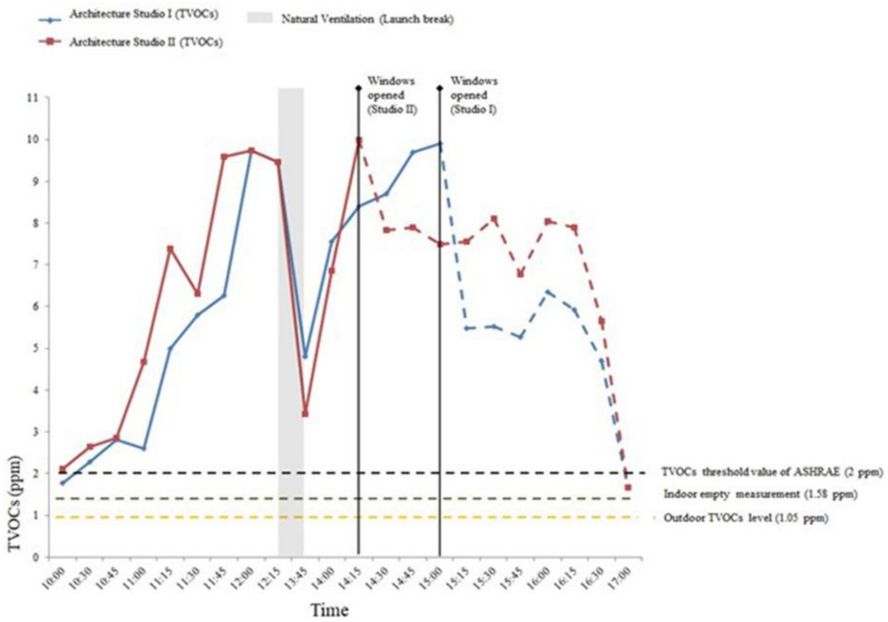

Figure 9 - TVOCs values in studios.

Particulate matter (PM)

With the maximum values at 12:00 for Studio I and II (45895 and 55616, respectively), the particulate matter ($PM_{0.3}$) levels in both studios remained below the limits (Figure 10). It can be said that the reason for the maximum values at 12:00 was that the students in the studios were on lunch break. With the completion of the model-making process in the studios at 16:00 and then the start of studio cleaning by the students, the $PM_{0.3}$ levels increased until 17:00 and reached 54384 in Studio I and 45236 in Studio II at 17:00. $PM_{2.5}$ particulate matter and PM_{10} coarse particulate matter levels were below the limits for both studios (Figures 11, 12).

The $PM_{2.5}$ level reached maximum values of 211 and 282 at 11:45 am for Studio I and at 12:00 pm for Studio II, respectively. It has also been observed in many studies that $PM_{2.5}$ levels increase at times when mobility increases (Guo et al., 2017, Zhang et al., 2016). As shown in Figure 11, the maximum $PM_{2.5}$ level was observed as 271 μm for Studio I and 128 μm for Studio II after the cleaning activities started. After the cleaning activity started, the PM_{10} level also increased, from 42 at 16:15 for Studio I, to 40 at 16:30 for Studio II (Figure 12).

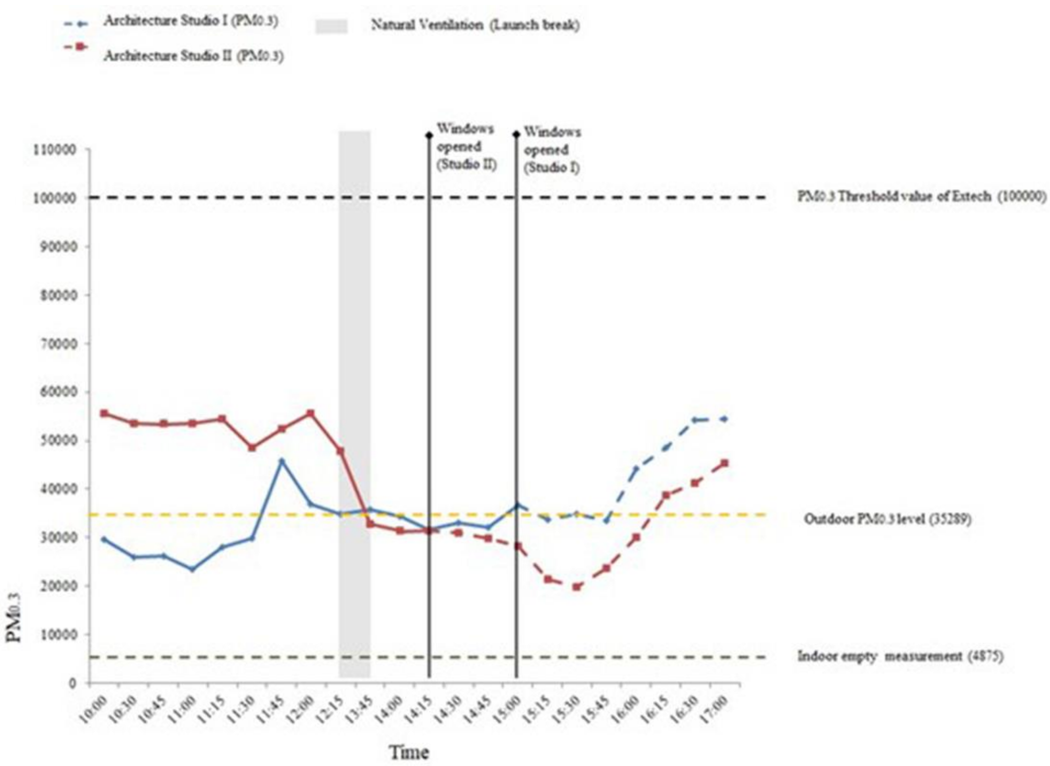

Figure 10 - $PM_{0.3}$ values in studios.

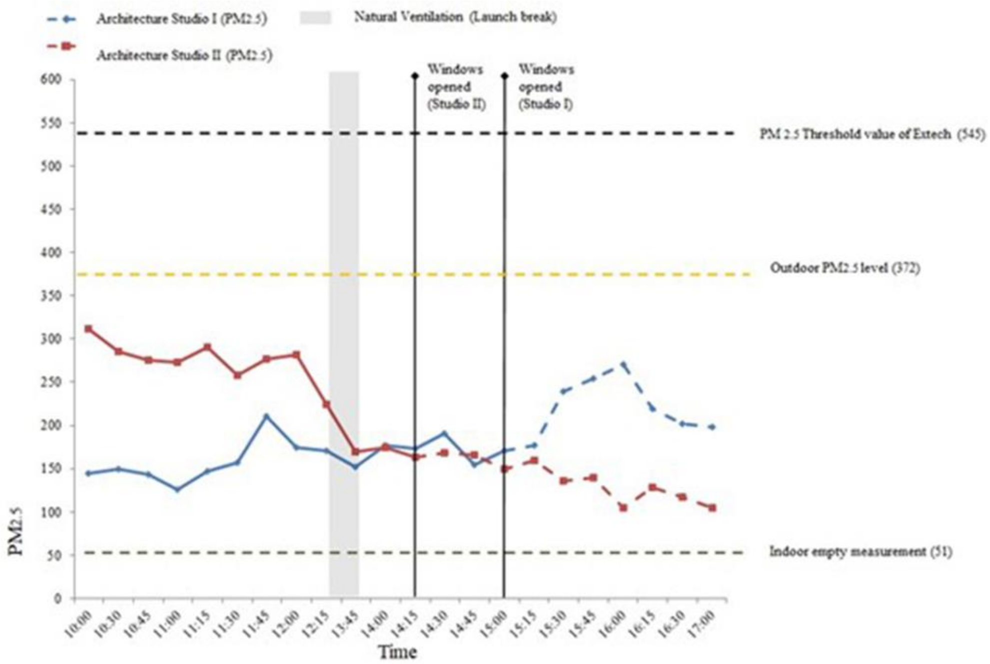

Figure 11 - $PM_{2.5}$ values in studios.

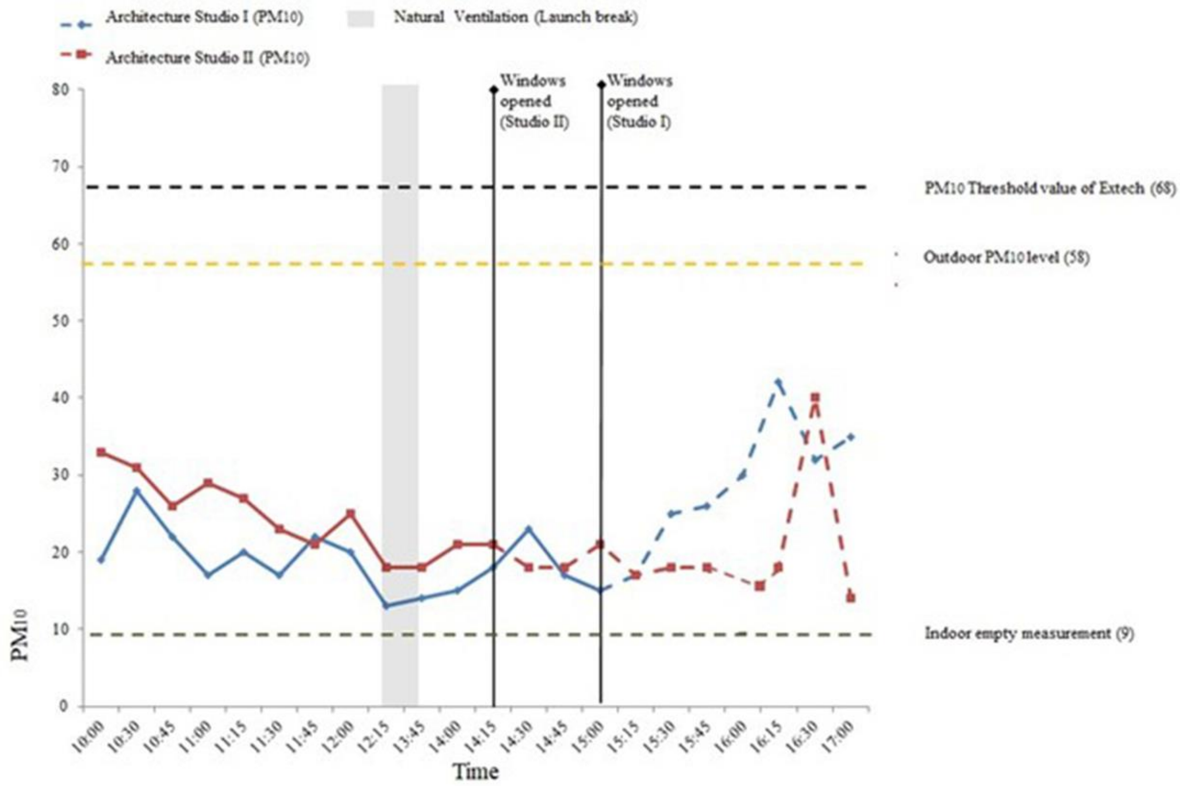

Figure 12 - PM_{10} values in studios.

Questionnaire Results

A questionnaire consisting of 12 questions was used to determine the satisfaction levels of the users regarding the comfort conditions of the studios. In addition to questions about indoor comfort conditions, the questionnaire also included questions about the presence of possible symptoms observed in individuals and whether these symptoms disappeared after leaving the building.

When the demographic data of the individuals interviewed in Studio I and II were examined, it was found that the age ranged from 19-22 years and the mean age was 20.7 years. In the questions directed to the individuals, a 7-point Likert scale response option, ranging from much poor (1) to much better (7), was presented.

In the survey conducted before the model making process in Studio I and II, participants indicated to feel poor (3), while they indicated to feel much poor (1,2) after the model making process. As can be seen in Table 4, while the users described indoor air quality as poor (3.1) before model making, they described it as much poor (1.1) after the completion of the model-making process. It can be said that the users' ratings related to thermal comfort and air movement velocity before and after the model-making process were similar, but their satisfaction level regarding air movement velocity increased due to the air flows that occurred as a result of the ventilation of the environment after the completion of the model-making process.

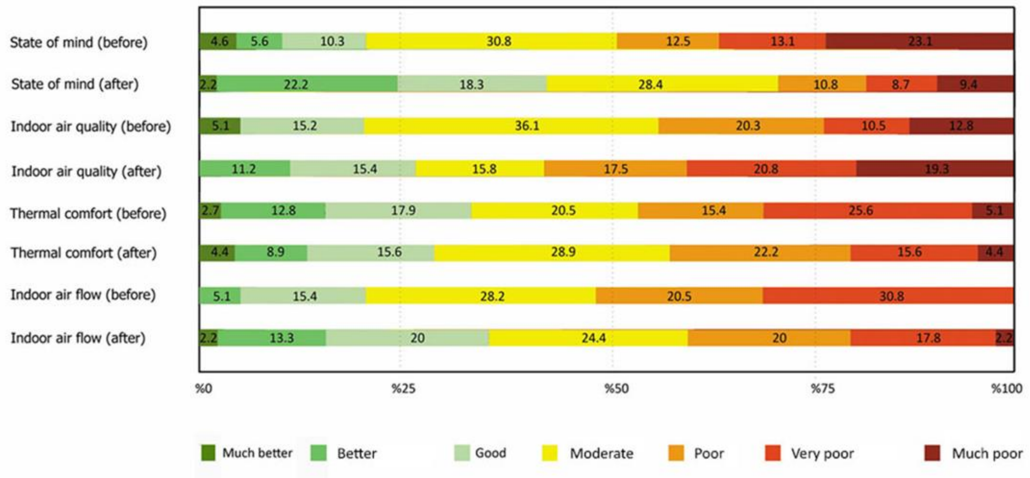

Figure 13 - Indoor air quality and thermal comfort questionnaire results for Studio I.

As can be seen in Figure 13, while 48.7% of the Studio I users felt psychologically poor (poor+very poor+much poor) before the model making process, this percentage decreased to 28.9% after this process. Before model making, 43.6% of the users described indoor air quality as poor, 20.3% as good, and 36.1% as moderate. It can be observed that these values changed to 57.6%, 26.6%, and 15.8% respectively after the model making process. The increase in poor feelings towards indoor air quality after the model making process can be explained by the pollution of indoor air due to activities in the room. Considering thermal comfort and air movement rate, it can be seen that before the model making process, 46.1% of the users described the thermal environment conditions as poor, 33.4% as good, and 20.5% as moderate. After the model making process, the satisfaction level regarding thermal comfort increased due to the increase in ambient temperature compared to the morning hours. Looking at the responses to the air movement speed questions, it is seen that 51.3% of the users described the air movement speed as poor before the model making process. This rate decreased to 40% with the movement of stagnant air in the environment in parallel with the opening of the windows after model making.

In Studio II, 34.5% of the users felt mentally poor before the model making process, and this percentage increased to 85% after this process (Figure 14). It was found that before model making, 36.5% of the users described indoor air quality conditions as poor, 13.8% as good, and 49.7% as moderate. These rates were found to be 86%, 5.3%, and 8.7% respectively after the model making. Compared to Studio I, the increase in the poor feeling of users in Studio II can be explained by the relationship between the size of the room and the number of users.

In terms of the thermal comfort conditions, it can be seen that the users are more satisfied with the indoor thermal conditions before the model making process. While thermal comfort conditions were defined as poor by 41.3% of the users and good by 13.8% before model making, these values changed to 60.6% and 6.1% respectively after model making. Air movement velocity was classified by 41.3% of the users as poor and by 17.3% as good before the model making process. Unlike Studio I, the decrease in satisfaction with air movement speed in Studio II after the model making process even when a window is open in the environment can be explained by factors such as lack of adequate fresh air, orientation status, and people/area ratio.

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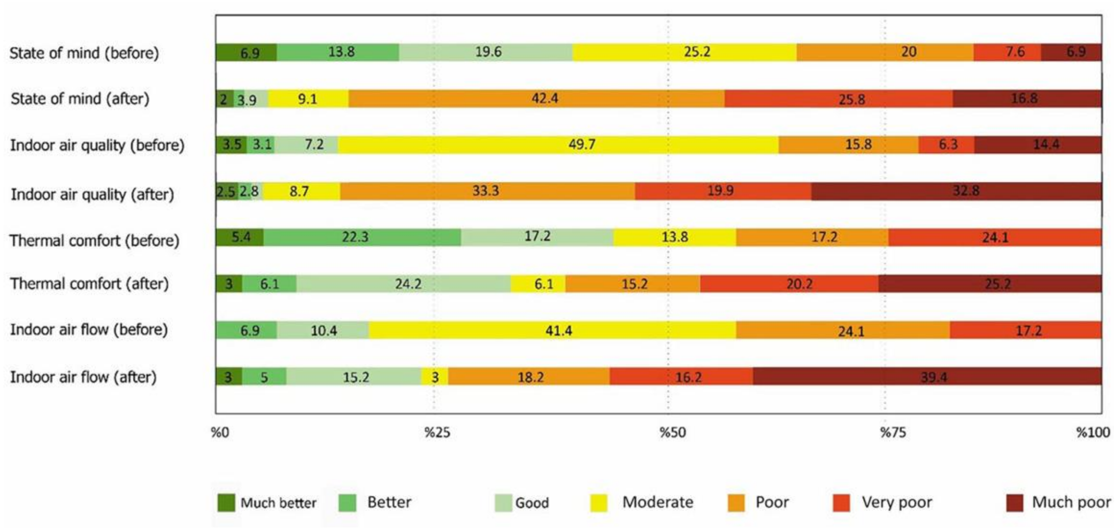

Figure 14 - Indoor air quality and thermal comfort questionnaire results for Studio II.

In order to determine the symptoms of the sick building syndrome in the questionnaire, the users were asked questions about possible symptoms and whether these symptoms were alleviated when they left the building. It was determined that Studio I users most frequently complained of fatigue (89.7%), headaches (43%), poor performance (33.3%), and eye itching (23.1%) (Figure 15). After the model making process, all symptoms increased except fatigue, headache, and eye itch. This shows that students come to the studio tired and with some symptoms. It can be said that the increase in the number of users experiencing symptoms such as bad smell (42.2%), dizziness (28.9%), and shortness of breath (26.7%) after the model making process is due to the increase in the amount of CO_2 and TVOCs in the room. In their study conducted in office buildings, Lu et al. (2015) showed that the symptoms of nasal congestion, shortness of breath, irritability, and dizziness developed in parallel with VOCs. In their study carried out using measurement and questionnaire methods, Fernandez-Aguera et al. (2019) found that dizziness, dry skin, headache, and fatigue symptoms were associated with increased CO_2 concentration. In their study conducted in selected office buildings from different countries, Sakellaris et al. (2020) found that most common symptoms observed were eye irritation, headache, drowsiness, and fatigue, and these symptoms were mainly caused by VOCs and CO_2. When these symptoms were evaluated considering the gender factor, it was found that women had more symptoms than men and complained more about their environment.

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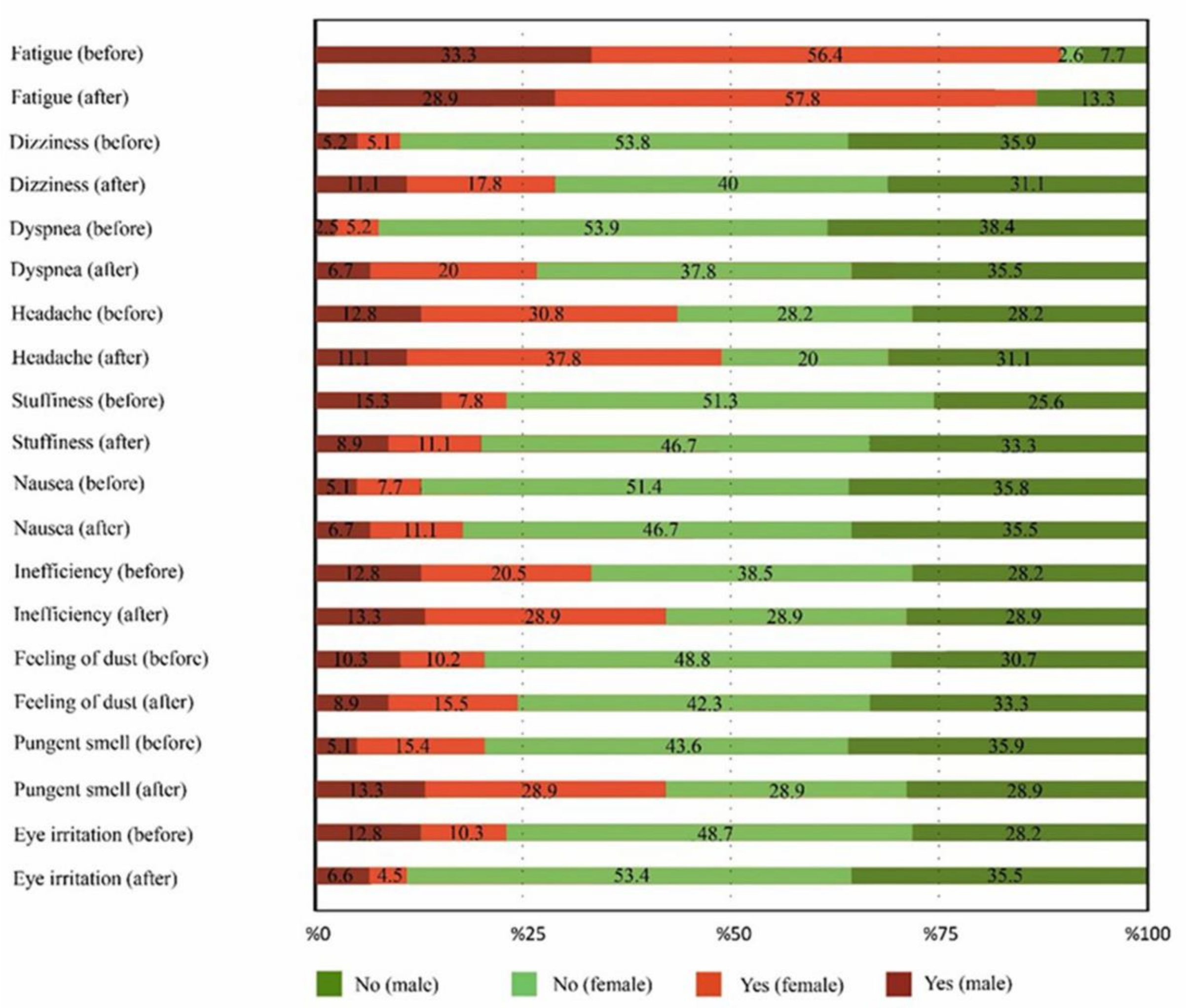

Figure 15 - Symptoms related to IAQ for Studio I.

As can be seen in Figure 16, results showed that the users in Studio II complained most about fatigue (58.6%), inefficiency (31%), headache (27.6%), and dyspnea (20.7%). After the model making process, increases were observed in all mentioned symptoms, and the most increased symptoms were inefficiency (72.7%), dyspnea (69.7%), headache (69.7%), pungent smell (66.7%), feeling of dust (60.6%), and dizziness (48.5%). Considering the similar demographic characteristics and activity status of the subjects, it can be said that the presence of more symptoms in Studio II than in Studio I and the increase of each symptom after the model making process may have been due to the smaller space, insufficient fresh air, and low space/user ratio. When the symptoms were evaluated taking into account the gender factor, it was seen that similar to Studio I, women had more symptoms and complained more than men.

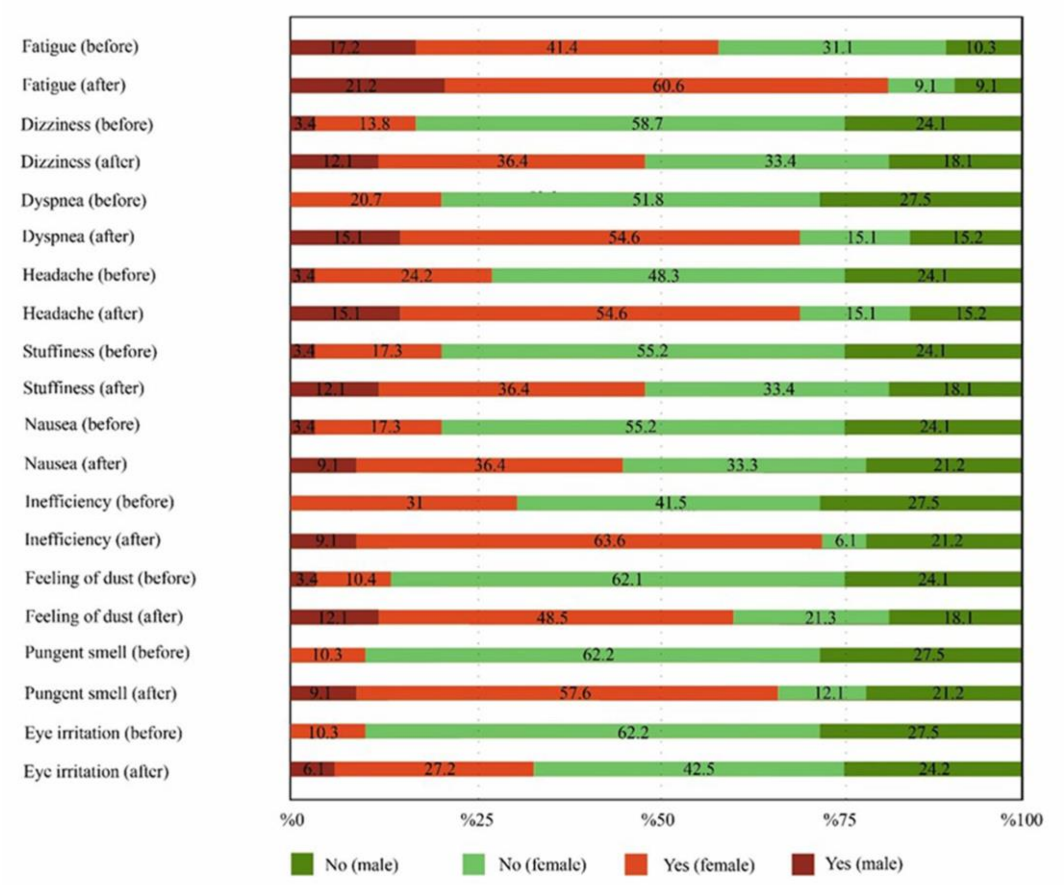

Figure 16 - Symptoms related to IAQ for Studio II.

CONCLUSION

Insufficient fresh air in architecture studios is one of the problems that hinder the intense training pace of architecture students. This problem is mostly experienced during the model making process in the studio. In addition to materials used by students for model making, inappropriate ventilation conditions and inadequate room volumes cause students to experience health problems during model-making processes. Thermal, visual, and acoustic comfort parameters play a role in studio design. In addition, measurements of thermal comfort, air pollutants, and real data obtained from field studies conducted with architecture students are important for optimizing IAQ and thermal comfort of studios. In this study, IAQ and thermal comfort status during the model-making process in architecture studios in the winter season was investigated and the effect of this situation on students was studied. The data obtained in the study is empirical evidence of the need for mechanical ventilation in addition to natural ventilation in studios.

Results of the study conducted on two studios showed that the TVOCs level reached 9.74 ppm approximately 2 hours after the start of the model-making process. This value was 5 times higher than the threshold limit value. In the studios, the CO_2 level reached 1000 ppm, which is the threshold value set by ASHRAE, within 30-45 minutes. Thermal comfort is also crucial in terms of the quality of students' study environment. The results of this study, which was also supported by a survey, revealed that when the windows were opened, thermal comfort in the studios and students' satisfaction with thermal comfort decreased. These results show the importance of improving the thermal situation and IAQ in studios.

This study presents data on the relationship between indoor air quality and thermal comfort, which should be taken into account in the design of studios in buildings where architecture classes are taught, as well as indoor air quality and satisfaction of users with thermal comfort during the model making. Separating modeling studios from drafting studios and grouping studios with similar ventilation needs in a specific area, as well as zoning space for energy efficiency, are among the recommendations. In addition, given the number of students who will use the space, it is important to include additional mechanical ventilation systems in cases where natural ventilation and fresh air cannot be provided. Future studies should focus on the quantitative relationships between the number of students, studio space, and fresh air required in architectural model studios, which were not investigated in this study.

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Conflict of Interest Statement

There is no conflict of interest for conducting the research and/or for the preparation of the article.

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Ethical Statement

Ethics committee approval (Decision no: 2020/03-15) was obtained from Karabük University. All procedures followed were in accordance with the ethical standards.

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Author Contribution Statement

A. Fikir / Idea, Concept	B. Çalışma Tasarısı, Yöntemi / Study Design, Methodology	C. Literatür Taraması / Literature Review
D. Danışmanlık / Supervision	E. Malzeme, Kaynak Sağlama / Material, Resource Supply	F. Veri Toplama, İşleme / Data Collection, Processing
G. Analiz, Yorum / Analyses, Interpretation	H. Metin Yazma / Writing Text	I. Eleştirel İnceleme / Critical Review

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