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Evaluation of Thermal Comfort Online Simulation Tools Usage Through Distance Education Process in an Applied Graduate Course

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Abstract

Through Covid 19 pandemic, education field has experienced mandatory transition to distant education. The case study held in Indoor Comfort Management postgraduate course. In order to examine how direct sunlight affects the adaptive thermal comfort of the user, simulations were made with online tools to evaluate thermal comfort within the scope this course at Yaşar University. The SolarCal and ComfTool of CBE online tools are used. This article aims to question the contribution of online simulation tools to education via a questionnaire given to students to grasp aspects of adaptive thermal comfort. The use of these aforementioned online tools and formulas can enrich studies and draw conclusions in limited facilities for professionals especially for architectural and engineering industries. The results of the survey will be analyzed to ensure the applicability of such a methodology in similar learning environments for easy understanding of the various adaptive thermal comfort indices at once.

Keywords: *Thermal comfort, distant education, online tools, interior design, indoor comfort.*

Uzaktan Eğitim Sürecinde Isıl Konfor Çevrimiçi Simülasyon Araçlarının Uygulamalı Bir Yüksek Lisans Dersinde Kullanımının Değerlendirilmesi

Öz

Covid 19 pandemisi ile birlikte eğitim alanında uzaktan eğitime zorunlu bir geçiş yaşanmıştır. Örnek olay çalışması İç Mekan Konfor Yönetimi yüksek lisans dersinde gerçekleştirilmiştir. Doğrudan güneş ışığının kullanıcının adaptif termal konforunu nasıl etkilediğini incelemek amacıyla Yaşar Üniversitesi'nde bu ders kapsamında termal konforu değerlendirmek için çevrimiçi araçlarla simülasyonlar yapılmıştır. CBE çevrimiçi araçlarından SolarCal ve ComfTool kullanılmıştır. Bu makale, uyarlanabilir ısıl konforun yönlerini kavramak için öğrencilere verilen bir anket aracılığıyla çevrimiçi simülasyon araçlarının eğitime katkısını sorgulamayı amaçlamaktadır. Yukarıda bahsedilen çevrimiçi araçların ve formüllerin kullanımı, özellikle mimarlık ve mühendislik endüstrileri için profesyoneller için sınırlı imkanlarda çalışmaları zenginleştirebilir ve sonuçlar çıkarabilir. Anketin sonuçları, çeşitli uyarlanabilir termal konfor endekslerinin bir kerede kolayca anlaşılması için böyle bir metodolojinin benzer öğrenme ortamlarında uygulanabilirliğini sağlamak için analiz edilecektir.

Anahtar kelimeler: *Isıl konfor, uzaktan eğitim, çevrimiçi uygulamalar,iç mekan tasarımı, iç mekan konforu.*

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1. Introduction

With the effect of the COVID-19 pandemic, distance education has become mandatory and the online education process is well-adopted by many organizations in the field. For educators and students, it is important to conduct distance education clearly to enable continuation of the learning process. For this reason, online tools that will contribute to learning, which are used in distance education have become more important. Online education should be conducted not only as a transfer of knowledge, but as an experiential process (Hodges et al., 2020). The connection between the student and the lesson is created by the instructors through planning the content of the lesson with versatile tools. Planning online learning requires a focus not only on defining the content but also on how to support the different types of interactions that are important to the learning process. During the transition to online education, many curricula needed to be updated accordingly. While creating online educational content, it was tried to enrich the education and training with experiential methods. Compared to the face-to-face education approach, how distance education/ online education, affects the education and learning of students will be examined through this article.

Mandatory online education was held in a graduate course named Indoor Comfort Management at Izmir Yaşar University, in the spring semester of 2019-2020. The course, which was face-to-face at the beginning of the term, continued online starting on week 7 due to COVID-19 pandemic uncertainty and concerns. After the change in the syllabus, some studies and experiences planned to be tested with in-course exercises, converted to be conducted with online tools. This course examines indoor comfort parameters (mainly thermal comfort) and occupant satisfaction. Thermal comfort means keeping the indoor thermal conditions at a certain level for user satisfaction. It has been a common practice to discover building occupants' satisfaction with the indoor environment by assessing their perception of thermal comfort. Thermal comfort, one of the main environmental factors required to ensure quality in the interiors, was analyzed with online tools in parallel with self-testing on how students felt in their environments. A total of 9 studies were carried out. With the limitations of online training, tools based on CBE's (Center for Built Environment) SolarCal and Comf Tool and ASHRAE Standards were used to analyze adaptive thermal comfort levels, created and shared by Berkeley Lab, UCL.

This study explains how online tools can play an active role in adaptive thermal comfort education and what level of tutoring is available for design students. The survey conducted for this specific study expresses how the online simulation tools used by the students help them to comprehend the thermal comfort aspects of the interior space they live in by comparing survey results and calculation method results. The aim is to see how these tools may contribute to education especially when face-to-face option is not active.

In the distant education process with online tools, experimenting values of adaptive thermal comfort parameters play an important role with simulations. Therefore, in this study, experiments were conducted on two different days (Sunny and Cloudy to see the effect of sun radiation) in the study. The different parameter values entered caused the students to compare two different situations for their internal environment included in the experiment and to master the validating tools online. In distance education, the use of online tools will be explained as a practical and instructive method that can be experienced by all users in the future.

The aim of this study is to learn the contribution or challenge on education by integrating two different online simulation tools about thermal comfort in comparison to applied testing. The effect on students' learning within the scope of the Indoor Comfort Management course during distance education is investigated via online surveys.

1.1. Literature Review

The literature of this study is classified under three different subjects. The research that constitutes the thermal comfort studies related to online basic simulation tools has been examined first. The studies describing the online tools usage in online education constitute another part of the literature

section and finally, a literature study on the use of online tools in thermal comfort studies as a combination of the two has been investigated.

1.1.1. Thermal comfort studies related to online basic simulation tools

People spend most of their time indoors, therefore indoor environmental quality (IEQ) appears to be a major concern. IEQ is a combination of 4 main environmental factors as indoor comfort, and thermal comfort, indoor air quality, acoustic comfort and visual comfort (Pereira et al., 2014). Thermal comfort is the main concern of the upcoming case study, which is also a subject related to the satisfaction of the occupants. Indoor spaces should be comfortable for the occupants and thermal sense levels should be within their acceptability limits (Su et al., 2023; Uzun & Pakdamar, 2023; De Dear & Brager, 2002; Nicol & Humphreys, 2002; Brager & De Dear, 1998).

According to the scanned literature, there are many studies on thermal comfort in different fields. Designers engineers, and architects have carried out different study perspectives. Some studies are created by using various online tools and subjective surveys made to users. Research conducted by measurement and questionnaires for high school students in Portugal showed that the temperature outside the comfort zone was detected, but it was stated by the students that this situation was not disturbing (Pereira et al., 2014). It was understood that the measurements and the subjective evaluations of the building occupants were parallel.

Other studies are conducted with online simple simulation tools such as SolarCal, CBE thermal comfort tool, and AccuRate. Such studies have focused on environmental parameters such as air temperature, relative humidity, clothing insulation, metabolic rate, and air velocity, and using Fanger 7-point scales, the thermal sensation and thermal disturbances of the building occupants were tried to be evaluated.

The study of Arens et al. (2015) describes SolarCal, as a new public online web-based tool for predicting solar effects on comfort. ''The SolarCal model computes an increase in MRT equivalent to shortwave gains from direct, diffuse, and indoor-reflected radiation on a person. This is used to compute PMV using the method prescribed in ASHRAE Standard 55-2013'' (Arens et al., 2015). SolarCal, which is used in this study, says that it can be used at the beginning of architectural and engineering designs for the user to prevent the negative effect of the sun on the user, which will affect the comfort level.

There is a study describing the CBE thermal comfort tool, which is the tool used in the online course. It is the last version compatible with ANSI/ASHRAE-55 (2017), ISO-7730 (2005), and Comite'Europe'en de Normalisation, C. E. N. 16798–1 (2019) Standards (Venticool.eu., 2022). The Center for the Built Environment (CBE) is an article explaining that the thermal comfort tool is a free and open-source online tool for calculating and visualizing thermal comfort indices. This tool, which can be used without any practical analytical or programming skills, is used by more than 49,000 users each year (Tartarini et al., 2020). The authors explain that it is used in different fields such as education, research and architecture. The CBE thermal comfort tool is an online tool with a high rate of use thanks to its practical and easy accessibility, as well as being accepted as an official comfort tool by ASHRAE in 2017.

Huizenga et al. (2006) revealed a study that determined the level of thermal comfort with a questionnaire. In this study, it is aimed to conclude whether office workers are satisfied with the comfort related to indoor thermal conditions. More than 34,000 questionnaire responses were given in the study conducted in 215 buildings (Huizenga et al., 2006). As a result of this study, inferences can be made that it affects productivity in office environments. There are implications for how to increase occupant comfort and productivity (Huizenga et al., 2001).

1.1.2. Online education and online tool studies

In this study, a literature review on online tools conducted that will establish the relationship between online training and easy thermal comfort assessment. Shared literature has been focused on explaining the effect of easily accessible online tools in teaching. With online education, it has been revealed that instructors and students use different lecturing techniques to enrich the educational content.

Campos et al. (2020) in their study, which encourages students' direct participation in simulation-based knowledge, four different situations that encourage intrinsic motivation and use different simulation

tools in applied learning activities designed by instructors and developed under their supervision and guidance are analyzed as an example. Training supported by simulation tools creates a good method for studies as it allows realistic models. It facilitates and improves learning processes (Campos et al., 2020; Hodges et al., 2020).

Holmberg (1977) defined distance teaching/education as a method of imparting knowledge, skills and attitudes which is rationalized by the application of division of labor and organizational principles as well as by the extensive use of technical media, especially for the purpose of reproducing high quality teaching material, which makes it possible to instruct great numbers of students at the same time wherever they live (Holmberg, 1977).

1.1.3. Online education and thermal comfort studies

A literature review has been made on online tools used in thermal comfort education. There are studies involving combinations of online simulation tools and adaptive thermal comfort.

Albatayneh et al. (2017) describe the calculation program called AccuRate an evaluation software that assigns a star rating to residential buildings in Australia based on the calculated annual heating and cooling energy requirements. This approach includes improving the overall thermal performance of building users.

Schiavon et al., (2014)'s paper describes a web application for thermal comfort visualization and calculation according to ASHRAE Standard 55. This online and free tool emphasizes that it can be used by students, instructors, architects, and engineers. Given its free availability and high interaction, another web application is suggested as a form of learning in postgraduate and undergraduate building courses or where other users can evaluate the thermal comfort results of their designs (Schiavon et al., 2014).

2. Material and Method

Thermal performance evaluation for the studio case study was prepared by using the adaptive thermal comfort model in living rooms in different locations of Izmir. In the study using 4 different methods, 2 different online tools were used. SolarCal was used in step 1, CBE Thermal Comfort in step 2, Survey questions were asked from occupants in step 3, and the final step was calculating PMVnew with the help of manual SolarCal formal. "Exposure to sunlight indoors produces a substantial effect on an occupant's comfort and on the air conditioning energy needed to correct for it, yet has in the past not been considered in design or thermal comfort standards (C.E.N., 2007). A public online model of the effects of solar radiation on human heat gain and comfort has been developed to make this possible. SolarCal is a whole-body model for ease of use in early design. Its predictions compare closely (<0.1 PMV mean absolute error) the results of a human subject test. It can be used to determine the allowable transmittance of fenestration in a perimeter office" (Arens et al., 2015, p.5).

Three different methods were applied to define thermal comfort in the course content and the results were compared through the second half of the semester. These were done with online tools, surveys, and calculation methods. To learn the contribution of the online tools of the suggested tutorial, a questionnaire was presented to the participants of the course to evaluate. Adaptive thermal comfort education can be complex so student views should be considered. A questionnaire was conducted including the study methods they used while learning and their evaluation of their ideas after this study in 2021. The main method of this specific study is a questionnaire (Appendix I) prepared to understand the contribution of the methods and online tools used for the work done in the course through online education. The evaluation part is the most valuable output.

Material consists of three different methods used for the exercise:

a. Online thermal comfort simulation tools

Thermal comfort prediction and visualization tools may help designers and building operators to better design, operate, and understand thermal comfort (Schiavon et al., 2014). It is important for designers

to design their designs inline with indoor comfort parameters. Tools that help us to understand the level of indoor thermal comfort used for teaching purposes in this applied course.

With the limitations of online education, to analyze the adaptive thermal comfort levels, the SolarCal and Comf Tool of CBE (Center for the Built Environment) generated and shared by Berkeley Lab, UCL based on ASHRAE Standards. These online tools, which constitute the objective part of the study, were used in two different conditions, on sunny and cloudy days, with different values of radiance (and related MRT) added as input. The parameters considered in simulations are dry bulb air temperature (DBT), mean radiant temperature (MRT), air velocity (m / s), relative humidity (RH), metabolic rate (BMR), and clothing insulation (clo) (Fanger, 1970). Thermal comfort is defined as the predicted mean vote / percentage of people dissatisfied (PMV / PPD). The range of PMV values is important in determining thermal comfort ranges. Another index for thermal comfort is PPD. This index, developed in conjunction with PMV, shows the proportion of people who are dissatisfied with the ambient temperature defined by Fanger first in 1970 and feel uncomfortable.

Thermal comfort is defined by the ASHRAE 55 standard as a condition of mind expressing satisfaction with the thermal environment. According to ISO, Thermal comfort can be affected by different types of physical, physiological, or psychological processes. Adaptive thermal comfort training is provided to learn the change in people's comfort sensations due to the cultural and physical differences of the environment and to adapt accordingly.

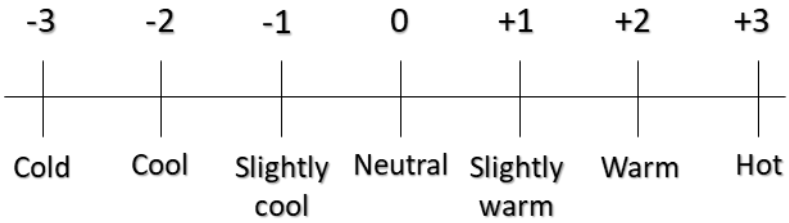
b. Adaptive thermal comfort survey

Physical measurements alone are not sufficient to define the thermal sensations of the individual users. Therefore, in addition to the thermal comfort and adaptive thermal comfort simulations with online tools, surveys and formula calculations were also made. While defining the thermal comfort level of the environment in which they live, the students made a questionnaire with themselves and/or their family members using that area exposed to the sun in sunny day conditions.

Fanger 7-point scale

To understand the thermal sensation in the subjective result, a questionnaire was prepared using the Fanger 7-point scale original evaluation grade scale (Table 1). Occupants give points based on their thermal comfort in the environment survey given in the scale defined in Table 1 (Fanger, 1970).

Table 1. Fanger 7-point scale original evaluation grade scale (Fanger, 1970)



PMVnew formula

PMV model has later been questioned assessing the ability to predict thermal sensation (Humphreys & Nicol, 2002; Baizaee et al., 2012). By using the formula called PMVnew method provided by Humphreys & Nicol (2002) about adaptive thermal comfort grading scale, a comparative evaluation of the results of the questionnaire with the PMV original scale adapted with the new PMV adaptive scale. Then, site results can be compared with online simulation tool results.

c. Prepared Survey on Online Tools Used in Online Education

In the context of this course, a survey was conducted to understand the impact of the simulations made online on students in thermal comfort education. This questionnaire was applied to a total of 9 people who attended the Indoor Comfort Management graduate course in the spring term of 2019-2020. The questionnaire has been prepared with such questions to determine whether the use of the

mentioned online tools contributes to students' learning or becomes a challenge. The effect of the thermal comfort indexes on the comprehensibility of the subject in the online tool experiment, where the variability according to different simulations is made, will be evaluated with the answers of the students who participated in this survey. The purpose of this survey is to understand the instructiveness of the online simulation tools through mandatory distance education process caused by COVID-19 pandemic.

Details of Methods applied:

With the COVID-19 pandemic, the syllabus of the Indoor Comfort Management course evaluated in this article has also changed as in many online converted courses. Online simulation tools have been added as an alternative for the course that cannot be carried out as planned at the beginning of the term. The fact that these tools can be used free of charge and online has caused students to continue their education efficiently.

a. Online thermal comfort simulation tools

Thermal comfort prediction and visualization tools can help designers better design, operate and understand thermal comfort. In this course, it was used for educational purposes for students. In the study conducted in the online course, the students determined the parts of their living spaces that receive direct sunlight as their study areas. The surveys were carried out in the spring days of 2020, in the 3rd and 4th weeks of April, in residential units. These case studies were carried out in the living rooms of houses in Izmir. Thermal comfort simulations were made using online tools. The online tools used in this study were used to find the effect of solar radiation and daylight on the PMV values of the participants. The SolarCal (MRT Calculator Tool of CBE) Tool was developed to quickly and easily understand the effect of sunlight in environments with simple geometries (Arens et al., 2015).

In addition, in order to better understand the effects of the sun, each participant made an online CBE Thermal Comfort Tool simulation, which does not take the sun as a parameter, and evaluated the results obtained from two online tools. SolarCal Tool, CBE Thermal Comfort Tool were used in this study. Conclusions are drawn by using the thermal comfort parameter inputs in both online tools.

CBE thermal comfort

With CBE's Thermal Comfort Tool related to ASHRAE Standard 55, air temperature, MRT result, airspeed, relative humidity, metabolic rate and clothing level of the occupant were used. Solar Cal adaptive comfort parameter value of MRT is added within this tool for simulation results.

SolarCal (MRT calculator tool of CBE)

It is an interactive tool that calculates and displays average radiant temperature (MRT) and estimated comfort within an area based on room surface temperatures and solar energy gain from windows and skylights (Tartarini et al., 2020).

Room dimensions, number of windows, window sizes, window glass (single or double glass), user's sitting position, floor, and wall materials, These are important for entering the emission values into the simulation tool as data. It is also effective in feeling the sunlight effect more.

The wall temperature is necessary for this simulation tool (Arens et al., 2015). By examining SolarCal research Solarcal inputs have been included. These inputs are window surface which determines of the subsurfaces to be treated as a window, alt (degrees from horizontal): solar altitude, az (degrees clockwise from north): solar azimuth, fbes: fraction of body exposed to sun, asa: average shortwave absorptivity, Idir: direct-beam (normal) solar radiation (W / m^2), Rfloor: floor reflectivity (Arens et al., 2015).

Simulations made with online tools were experienced by the students through dividing them into sunny and cloudy days. The families of the students were exposed to the sun by staying in the same position for about half an hour close to the window, where they spent time in their living areas on sunny and cloudy days in spring.

Each student has reached some inputs for simulation by using the temperature of the room he / she simulated and the weather information of the day (expected to be very similar in other parameters). Room dimensions and features also appear as different parameters. The emissivity values of the floor, wall and window materials of the room are used as inputs of the walls (Table 2). Window dimensions and window emissions are also written in the SolarCal online tool as factors affecting thermal comfort.

Table 2. The transmittance & emissivity values of materials (ThermoWorks, 2019)

Material	Light transmittance (T_{vis})	μ-value
Single glazed	0.90	5.68
Double glazed (Air filled)	0.81	2.83
Conventional double glazed unit	0.81	2.70
Double glazed unit with low-e coating	0.74	1.70
Argon filled double glazed unit with low-e coating	0.74	1.10
Polycarbonate panel	0.72	1.84
Double glazed (Argon filled)	0.70	1.40
Triple glazed (Krypton filled)	0.62	0.68

The Heating, Ventilating, and Air Conditioning system is not open during this experiment. A clothing value of 0.7 was obtained for occupants with long-sleeved T-shirts and long trousers. The students made experiments in this area with their family members. Students seated their families in a room with at least half an hour of sun to control their thermal feel on sunny and cloudy days. To analyze users' thermal sensations, questions were asked on the Fanger-7 point scale. Sun azimuth and sun altitude are found on the website for experiment day which is required for simulation (From https://www.sunrise-and-sunset.com/en/sun/turkey/izmir). Direct beam solar radiation input is found according to direct beam solar radiation on the solar altitude angle table (Table 3).

Table 3. Direct beam solar radiation on the solar altitude angle (Arens et al., 2015)

Solar altitude angle [o]	5	10	20	30	40	50	60	70	80	90
Direct beam solar radiation [W/m2]	210	390	620	740	810	860	890	910	920	925

b. Adaptive thermal comfort survey

Questionnaire questions were asked to occupants using the space after sitting on the windowsill for 30 minutes. The occupants' thermal sensation levels were defined by their answers to the questions. Fanger 7-point scale and PMVnew formula were used to reach the PMV value of the survey answers. The simulation results and the survey results were similar for the majority of course students.

PMV_{new} formula

Comparative evaluation is done by comparing PMV results obtained from simulations and the formula named as PMVnew method provided by Humpreys & Nicol (2002) to assess whether qualitative results were found. A new and still scientifically worked formula for adaptive thermal comfort.

PMVnew = 0.8 (PMV- DPMV- ASHRAE) *Formula 1*

*DPMV- ASHRAE = -4.03 + 0.0949Top + 0.00584 (% RH) + 1.201 (met * clo) + 0.000838Tout2 Formula 2*

c. Prepared Survey on Online Tools Used in Online Education

PMV model has later been questioned assesing the ability in predicting thermal sensation (Baizaee et al., 2012).

Within the scope of this study, questionnaire questions were prepared to be answered by 9 students who took the Indoor Comfort Management course at Yaşar University. In the online parts of the course, it has been tried to obtain information about how the online tools used affect students learning. In these survey questions, there are questions about the thermal comfort evaluation simulation that each student makes in his / her own environment. Along with the requirements of distant education, it was aimed to get the participants ideas about how online tools contributed or challenged the education process.

This questionnaire consists of 10 questions that target to learn how the online education is supported by online tools. The questionnaire was delivered to the students taking the course by e-mail. All students taking the course willingly participated in the survey and shared their opinions.

3. Findings and Discussion

This study explains a case study about the thermal comfort experience through, one of the parameters of indoor comfort, in the indoor management control applied course given at Yaşar University in the spring semester of 2019-2020. Simulations were made with online tools for generic thermal comfort and its adaptable thermal comfort coupling. The contribution of this to education will be concluded with the opinions of the students.

Distant education is a method of transferring knowledge, skills and attitudes that are rationalized by the application of division of labor and organizational principles, as well as the widespread use of technical knowledge (Peters, 1973).

Distant education brings new ideas and new approaches to creativity into students' minds (Kauser, 2021). Luna et al. (2018) tested the effect of integrating various learning strategies, namely simulations and case studies, into the curriculum of a Management Engineering course at the Universidad del Pacifico.

Among the many benefits provided by simulation training resources, their easy integration into blended and online courses is a notable fact that promotes their spread and popularity among universities and training centers worldwide (Campos et al., 2020).

It was concluded that the simulations managed by the instructors facilitate the development of the students' analytical thinking. With free online tools for LEED thermal comfort credits, thermal comfort calculations and visualizations, according to ANSI/ASHRAE-55 (2017), ISO-7730 (2005), and Comite'Europe'en de Normalisation, C. E. N. 16798–1 (2019) standards, architects, engineers or design students can easily define thermal comfort.

Online education has also contributed to the teaching, in example: thanks to the simulation tools used by the students that help them to understand the thermal comfort of their living environment. Simulations with online tools create an important experience in determining adaptive thermal comfort.

Within the scope of this study, questionnaire questions were prepared to be answered by 9 students took Indoor Comfort Management course at Yaşar University. In the online parts of the course, it has been tried to obtain information about how the online tools used affect students learning. In these survey questions, there are questions about the thermal comfort evaluation simulation that each student makes in his / her own environment. Along with the requirements of distant education, it was aimed to get the participants ideas about how online tools contributed or challenged the education process.

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When asked whether online tools are an advantage or a compelling factor for understanding thermal comfort sense, 3 of the students said it was an advantage, while 4 students said it was challenging, and 2 people were undecided (Figure 1).

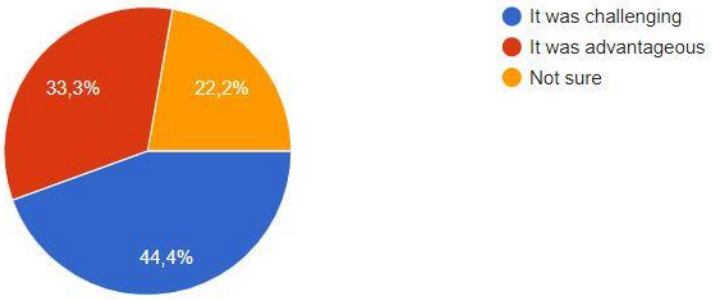

Figure 1. Chart created by author from Appendix I question "Do you think the use of more online tools for understanding applications of thermal comfort became a challenge or advantage for you?"

It is important for the instructors, who have a role in helping the students to adapt in distance education, to contribute to the lessons and explain the use of tools in an understandable way. Therefore, a question was asked the students about how the influence of the instructor affected this process. It represented 5 students strongly disagree while being evaluated as 1 strongly agree. The majority of the students said that the course instructor helped explain the online tools (Figure 2).

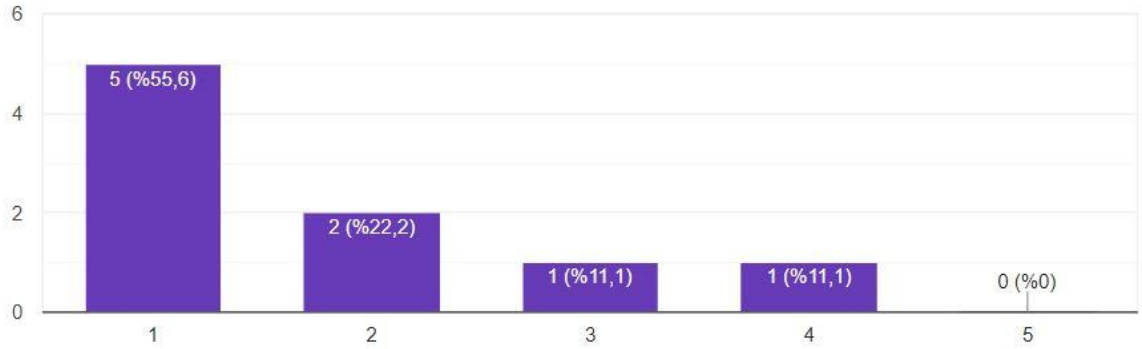

Figure 2. Chart created by author from Appendix I question "How do you agree that the course instructor explained and gave resources about the clear use of online tools? (1-5 Strongly Agree- Strongly Disagree)"

More than 50% of students agreed that SolarCal and Comf Tool of CBE (Center for the Built Environment) facilitate simulating adaptive thermal comfort measures are clear interfaces and freely accessible to be used in distant education (Figure 3).

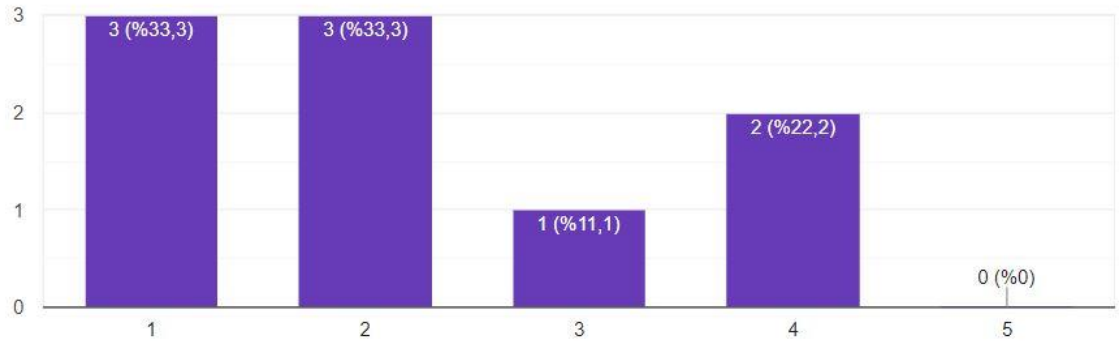

Figure 3. Chart created by author from Appendix I question "Are SolarCal and Comf Tool of CBE (Center for the Built Environment) online simulation tools used in distant education made it easier to simulate adaptive thermal comfort measures with its clear interface and free access? (1-5 Strongly Agree- Strongly Disagree)"

SolarCal and Comf Tool of CBE (Center for the Built Environment) online simulation tools used in distant education made it easier to simulate adaptive thermal comfort measures with its clear interface and free access.

After the simulations students conducted with the online tools, the participants were asked a question about the degree of their ability of using these tools. Some of the students who use online tools define themselves as average dominant, while others define themselves as above average (Figure 4). We can understand that the online tools used have easy and understandable steps during the application phase as all participants rated their usage level as average and above.

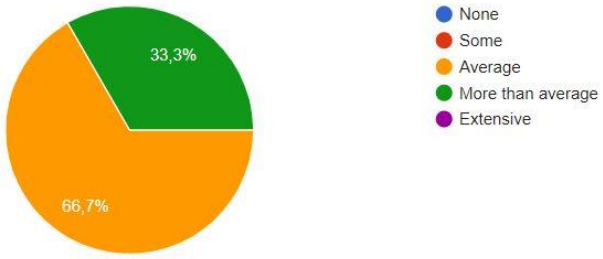

Figure 4. Chart created by author from Appendix I question "How would you rate your usage of online simulation tools introduced for rating adaptive thermal comfort?"

A question was asked to understand if the thermal comfort status performed gave similar results with different methods. In this question, 5 of the participants say that the results for the simulation and survey they conducted in parallel to understand the thermal comfort of the building occupants overlap. While 3 participants remain undecided, 1 participant says that the simulation and survey results do not match (Figure 5).

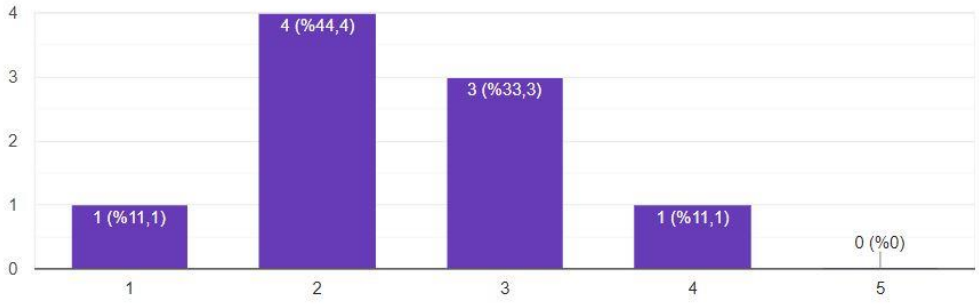

Figure 5. Chart created by author from Appendix I question "Did the simulation and the survey conduct parallel to understand the thermal comfort of the occupants give similar results as anticipated? (1-5 Strongly Agree- Strongly Disagree)"

The students agreed with the questionnaire that using online tools and exercise/case study/ test in the distant learning process helps to better understand adaptive thermal comfort (Figure 6).

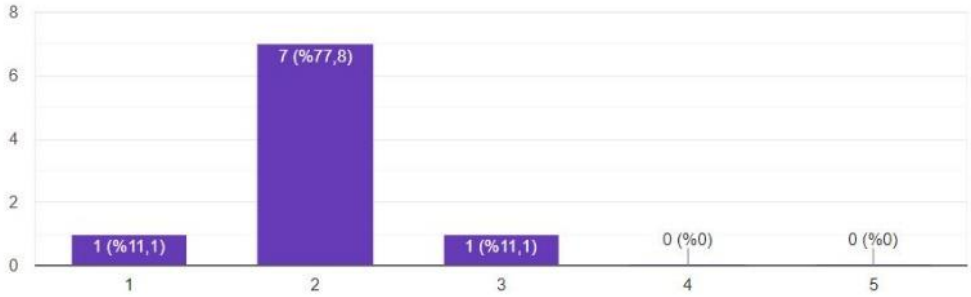

Figure 6. Chart created by author from Appendix I question "Through the test/case study exercise given, to what extend did you have the chance to understand the concept of adaptive thermal comfort measures? (1-5 Strongly Agree- Strongly Disagree)"

The question was asked that the effect of solar radiation on adaptive thermal comfort was experienced and simulated with redesigned online exercises and questionnaires. While 7 of the participants joined, 1 participant was undecided. 2 people did not participate in this judgement.

In an open-ended question (Question 10- What are the benefits and disadvantages of distant learning through online simulation tools in the Graduate Course INAR 5570 Indoor Comfort Management), the benefits and disadvantages of distant education implemented with online tools were asked. Some participants mentioned that the technical courses become more clear with online tools. According to these students, it is more beneficial to use online tools accompanying case study exercises for consolidating technical knowledge learning outcomes. These courses defined as courses, which becomes difficult to comprehend according to the answers of with distant education through this open ended question.

Despite these thoughts, majority of the students believe that if the experiments were done face-to-face in the classroom accompanying simulations, their understanding of newly introduced concepts would be even higher (Figure 7).

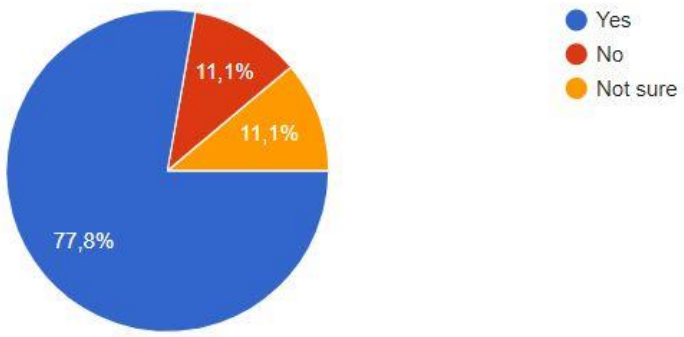

Figure 7. Chart created by author from Appendix I question "Do you believe if the experiments could be held in face to face class environment- your understanding of newly introduced concepts would be higher?"

The questionnaire answered by the course participant students stated that the simulations made with the online tools used in distant education also contribute to the development of the students graduate education, facilitate the understanding of the adaptive thermal comfort experience for future as well. However face-to-face interaction will be even more beneficial according to majority of student replies.

4. Discussion and Conclusion

As COVID-19 or similar pandemic conditions appear, distance education will continue to gain momentum all over the world. In distance education, the tools used are important for students to adapt to the online lessons and to receive the needed education level as aimed at a graduate course. In online courses, online tools have become a helpful element in understanding the lessons properly.

Various online tools are used in distance education (Buda, 2009; Puustinen & Rouet, 2009; Tang & Austin, 2009; Yaman et al., 2008). Agustí-Juan et al. (2017) says, simulation software and tools improve the learning experience when applied activities are also used by instructors in the education of students. Simulation-based activities in higher education programs have increased in recent years with computers becoming more personal and easy to move (Qudrat-Ullah, 2010).

Web-based online free tools offer important opportunities for designers and design students. It is known that the objective part of thermal comfort measurements are made with some online tools as a result of the guidance of the lecturer. One of the most actively used simulation programs is called ECOTECT and is made depending on the window configurations. In a study using ECOTECT 11.0, the Software was used to explain the effect of different building orientations on thermal comfort as well as validate it using measured data (Anand et al., 2017). This simplified tool can help architects and

building designers evaluate the performance of buildings in the early design stages with simple input parameters.

The adaptive thermal comfort approach helps building users achieve thermal comfort strategies effectively such as natural ventilation, seasonal clothing, solar exposure or control / shading (D'Ambrosio Alfano et al., 2014). There are tools that create some adaptive thermal comfort model. These are Accurate, CBE Thermal Comfort Tool, SolarCal, and some other tools described in the literature. CBE and SolarCal tools are used in parallel with a case study survey on thermal comfort levels within the sun exposed (MRT effect) rooms of student spaces under sunny and cloudy conditions with a few occupants. Material and adjustments of detailed methods are all given in Section 2 of this study.

Online tools are defined by students and educators as enriching the course content. The online tools used in the Indoor Comfort Management applied graduate course, which is the subject of this paper, have contributed to thermal comfort training according to results of the survey in Section 3.

A subjective evaluation of thermal comfort education has been made by volunteering graduate students (all class of 9) taking the Indoor Comfort Management course. All students who have taken and finalized the course participated this survey voluntarily. As experienced through the course and the transition to distance education, the effects of thermal comfort online tools used in distance education on students' learning process have been examined by this case study.

When we look at the results of the survey, the students said that the use of online tools made the learning process more useful and training was effective through online course. Despite this, most of the students stated that they preferred to use this online tool in a face-to-face education instead of distance education. Student responses are satisfactory as a result of seeing the benefits of using these tools in distance education. Thus, it can be concluded that online simulation tools that will contribute to thermal comfort education provide easy understanding and accessibility for the students and can be helpful to other groups as well.

Online simulation tools can also become important teaching tools in distance education or other professional platforms. Being easily accessible, they become practical teaching tools for students and other professionals in need. Students can develop their experiences with the online simulations they experience with the guidance of their instructors. In the distance education process, online tools can become an opportunity for students as well as these tools can be used in face-to-face education to reinforce the learning of new technical concepts such as adaptive thermal comfort. Multiple online tools introduced in paralel with real case testing studies are effective at experiencing the multi-dimensional components of adaptive thermal comfort and solar effect at once with simple interfaces.

Limitations of this study can be defined as:

- Number of participants is limited with defined graduate course students only.
- No past familiarity of students with the online simulation software knowledge and interest is questioned (P.S. Some students can be more tech-savvy than others).

Further study can be carried out on questioning the effect of the distance education of adaptive thermal comfort simple online tools on professional such as designer architects and mechanical engineers.

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Author Contribution and Conflict of Interest Declaration Information

1st Author % 80, 2nd Author % 20 contributed. There is no conflict of interest.

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Appendix I

ONLINE EDUCATION ASSESSMENT

The purpose of this research project is to understand the instructivity of the online simulation tools through mandatory distant education process caused by COVID-19 pandemic. This is a research project being conducted by Dilan Yanar at Yaşar University. You are invited to participate in this research project because you have taken the INAR 5570 Indoor Comfort Management graduate course in the spring semester of 2019-2020.

Your participation in this research study is voluntary. If you decide not to participate in this research survey, you may withdraw at any time.

The procedure involves filling an online survey that will take approximately 10 minutes. Your responses will be confidential and we do not collect identifying information such as your name, email address or IP address.

We will do our best to keep your information confidential. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only and may be shared with related scholarly research team.

Thank you for your participation.

1. Read and agree with the consent form

Uygun olanların tümünü işaretleyin.

☐ Yes

2. What do you think about revising the content of the course in line with distant education. Do you think use of more online tools for understanding applications of thermal comfort became a challenge or advantage for you?

Yalnızca bir şıkkı işaretleyin.

◯ It was challenging
◯ It was advantageous
◯ Not sure

3. The course instructor explained and gave resources about the clear use of online tools .

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly Disagree

4. SolarCal and Comf Tool of CBE (Center for the Built Environment) online simulation tools used in distant education made it easier to simulate adaptive thermal comfort measures with its clear interface and free access.

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly Agree	◯	◯	◯	◯	◯	Strongly Disagree

5. How would you rate your usage of online simulation tools introduced for rating adaptive thermal comfort?

Yalnızca bir şıkkı işaretleyin.

- ◯ None
- ◯ Some
- ◯ Average
- ◯ More than average
- ◯ Extensive

6. The simulation and the survey conducted parallely to understand the thermal comfort of the occupants gave results as anticipated.

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly Agree	◯	◯	◯	◯	◯	Strongly Disagree

7. Through the online exercises given, I had chance to understand concept of adaptive thermal comfort measures.

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly Agree	◯	◯	◯	◯	◯	Strongly Disagree

8. Using the online tools in the distant education process made me gain a better understanding of adaptive thermal comfort.

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly Agree	◯	◯	◯	◯	◯	Strongly Disagree

9. The effect of solar radiation on adaptive thermal comfort experienced and simulated with the redesigned online exercise and surveys.

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	
Strongly agree	◯	◯	◯	◯	◯	Strongly disagree