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THERMAL COMFORT IN SCHOOL ENVIRONMENTS: ANALYSIS OF THE THERMAL CONDITIONS OF THE CLASSROOMS OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, CAMPUS PONTA GROSSA - BRAZIL

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Abstract

The environmental conditions of the classrooms have influence on student performance student. Engineering courses in most offer classes full time, and lasting 5 years on average, leading students to spend much of their day in classrooms, which justifies the analysis of classrooms environmental conditions, such as: cleanliness, organization, storage, lighting, temperature, noise and school furniture. Thermal comfort is of great importance in student performance, as a school environment with excessive heat leads to fatigue and drowsiness. This article aimed to analyze the thermal conditions of the classrooms Federal University of Technology, Campus Ponta Grossa - Brazil, where there are students in the areas of Production, Electronic, Mechanical and Chemical Engineering. It was concluded that 90,90% of the rooms assessed meet the conditions for thermal comfort according to existing standards, while 9,1% of them do not. The two classrooms that did not meet the thermal specifications, one has presented conditions of heat and the other cold conditions.

Keywords: thermal comfort; classroom; engineering

Resumen

Las condiciones ambientales de las clases tienen influencia en los estudiantes y en el rendimiento de los estudiantes. Los cursos de ingeniería en su mayoría ofrecen clases a tiempo completo, u com duración de 5 años em pormedio y esto hace com que los estudiantes quedense gran parte del dia en clase, esto justifica el analisis de las clases, las condiciones ambientales tales como: limpieza, orden, conservación, iluminación, temperatura, ruído y mobiliário. El confort térmico es de gran importancia en el rendimiento de los estudiantes, como un entorno escolar con calor excesivo conduce a la fatiga y la somnolencia. Este artículo tiene como objetivo analizar las condiciones térmicas de las aulas de la Universidad Federal de Tecnología, *Campus Ponta Grossa - Brasil, donde hay estudiantes en las áreas de Ingeniería de Producción, Electrónica, Mecánica e Química. Se concluyó que el 81,82% de las habitaciones evaluó cumplir con las condiciones para el confort térmico de acuerdo con las normas existentes, mientras que 18,18% de ellos no cumplen. De las dos clases que no cumplían con las especificaciones térmicas, se ha presentado condiciones de calor, mientras que el otro presenta condiciones de frío.*

Palabras clave: *confort térmico*; *classe*; *ingeniería*

1. Introduction

Ergonomics seeks in essence to improve the conditions of the realization of human activities, both in relation to their instruments as the environments in which these activities are performed.

People spend much of their lives in the same environment, which can be either their workplace, especially in adulthood, and also in the school environment during much of his childhood and adolescence. Thus, the environment in which the daily tasks and learning occur is of great importance for the performance of school students. Observing the school environment through the study of ergonomics, the adequacy of the school environment involves issues of physical, such as cleaning, organization, storage, lighting, temperature, noise, and school furniture (SIQUEIRA; OLIVEIRA; VIEIRA, 2008).

Thermal comfort has great importance in the student's performance. According to Siqueira, Vieira and Oliveira (2008), a school environment with excessive heat leads to tiredness and drowsiness. But an environment with little heat ends up decreasing the concentration and attention of the student, because the body needs heat and increases metabolic activity to get warm.

This article seeks to analyze the thermal conditions of the classrooms of the Federal University of Technology, Campus Ponta Grossa - Brazil, where there are students in the areas of Production Engineering, Electronics Engineering, Mechanical Engineering and Chemical Engineering.

2. Thermal Comfort

The thermal comfort is one of the aspects which can affect a student's health and performance. The human body reacts to changes in temperature, trying to keep the body temperature stable. When the human being is in a hot environment, his body will tend to respond adaptively to this environment through thermoregulatory mechanisms, seeking to reduce internal heat production and heat loss aid (WITTERSEH et al, 2004).

In order to analyze a work environment, there are several procedures that have to be taken into account. Those procedures are standardized by ISO 7730:2005 and ISO 7726:1998, and they standardize principles of measurements, the equipment and sensors that must be used to measure environmental variables, measuring heights, and other principles.

The standard ISO 7730:2005 presents an index called PMV: Predicted Mean Vote, which represents the thermal sensation that a subject feels at the moment when measurements were carried out. The index result is given according to Table 1, and represents calculated thermal sensation:

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

Table 1 – Seven-point thermal sensation scale (Source: ISO 7730, 2005)

ISO 7730:2005 says that there are four environmental variables that must be measured to analyze thermal comfort, as follows: air temperature, air velocity, mean radiant temperature (calculated by measuring black-globe temperature) and relative humidity. In addition, there are two personal variables: thermal insulation and metabolic rate, which are collected by asking the students through a questionnaire.

After collecting the four environmental variables and the two personal variables, the PMV index is calculated, and the result is interpreted according to Table 1. The calculation was performed by the free software Analysis 2.1 CST, created by the Federal University of Santa Catarina (UFSC).

3. Methodology

3.1. Pilot study

This study first developed a pilot study to determine the sample size of classrooms that needed to evaluated and where the measurement equipment would be placed to measure the environmental variables in each classroom. In this pilot study, it was used a rectangular grid as shown in Figure 1 below, for each classroom. It is possible to observe from the figure that the classroom was divided into 15 points, where were carried out temperature measurements of the pilot study.

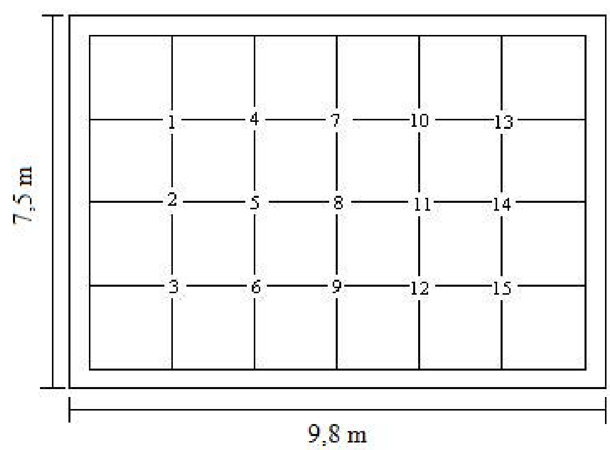

Figure 1 – Rectangular grid (Source: Authors)

The temperature was measured in all 15 points at the same time through 15 Data Logger HOBO's, which are capable of measuring temperatures of -20 ° C to +70 ° C, precision ± 0.7 ° C at 20 ° C , response time of 15 minutes and a storage capacity of up to 7944 data. The measurements took 15 minutes in each classroom and the data were stored every 5 minutes.

The university has 48 classrooms, divided in three blocks. For the pilot study 20% of the classrooms were measured. To determine the point of measurement, for each classroom the average of temperature was calculated, and the point of measurement was the one which had the temperature closest to the average of the entire class.

To calculate the sample size, the following formula by Triola (2005) was utilized:

$$n = \frac{N.\sigma^2.\left(Z^{\alpha}/_{2}\right)^2}{(N-1).\epsilon^2 + \sigma^2\left(Z^{\alpha}/_{2}\right)^2}$$

The result of this calculation was that for the population of 48 classrooms of the university, it would be necessary to measure 22 rooms, to be a representative sample. The classrooms were randomly chosen in each block, maintaining the proper proportions to the total amount of rooms in each block.

3.2. Definitive study

After having done all the procedure mentioned in the pilot study, this phase of the study aimed to measure the environmental variables and collect personal variables using questionnaires, in order to evaluate the thermal comfort of the classrooms. The realization of definitive measurements occurred during the course of the lessons.

The necessary variables were measured every 3 minutes over a period of 30 minutes. Measurements were initiated after 20 minutes of class, due to the required response time of the measurement equipment, and also so that the occupants can do the maintenance of its temperature to adapt to the environment. This is necessary due to differences in conditions between the internal and external environment, and naturally the occupants may feel the need to wear or remove any piece of clothing.

The equipment used to measure the environmental variables was the *Confortímetro Sensu®*, with sensors to measure air temperature, air velocity, globe temperature and relative humidity, and connected to a computer that saved acquired data every 3 minutes. The sensors were put in the environment 20 minutes before starting measuring the variables, because of the response time of the black-globe temperature sensor.

For the collection of personal variables the occupants answered questionnaires. In this questionnaire there was a table with various clothing items, where the occupant of the environment should describe their dressing for the thermal insulation of their clothes were determined. Furthermore, the occupant was also questioned about their metabolic rate and their thermal sensation at that moment.

The results were analyzed and the PMV index was calculated by the software Analysis 2.1 CST, created by the Federal University of Santa Catarina (UFSC).

4. Results

It was measured the following environmental variables: air temperature, air velocity, relative humidity and black globe temperature; and 190 students also responded to a questionnaire asking about their cloth insulation and metabolic rate.

For each user, it was determined the thermal insulation of your garment, using the software Analysis 2.1 CST. With environmental data at hand, it was then possible to calculate the value of the Predicted Mean Vote (PMV) for each user, and then calculated the mean of these values for each environment, to verify that your environment meets the current standards of comfort. The values of the environmental variables used are the average of each parameter, over a 30 minute measurement.

The PMV index was calculated for each classroom, and compared to ISO 7730:2005. In Table 2 is possible see the collected data for four classrooms.

Classroom	**Air T (ºC)**	**Globe T(ºC)**	**Rel. Umidity (%)**	**Air Speed (m/s)**	**PMV**
G-101	20,19	20,34	72,36	0,01	-0,15
H-207	21,93	22,14	73,24	0,01	-0,12
G-106	27,69	27,43	52,04	0,20	0,58
LSD	19,40	19,38	73,22	0,02	-1,016

Table 2 – Results for four classrooms (Source: Authors)

According to ISO 7730/2005, which discusses the determination of the PMV a thermally comfortable environment is one in which the PMV lies within the range of -0,5 to 0,5. Thus, even if there is a difference between the thermal sensation and the calculated PMV, if the value of PMV is within this range, the environment can be considered comfortable.

Of the 22 classrooms evaluated, only two can be considered uncomfortable: G-106 and LSD. The room G-106 presented an index greater than 0,5 and the room LSD presented an index smaller than -0,5. The other 20 classrooms can be considered thermally comfortable.

5. Conclusion

This study sought to evaluate the thermal comfort of the Federal University of Technology, Campus Ponta Grossa. For this, it was conducted a pilot study, which determined the sample size required for the evaluation of environments, and where the measurements should be carried out in each classroom. Subsequently, final measurements were carried out. In this phase were measured environmental variables and personal variables were collected through a questionnaire.

From the thermal point of view, 22 environments were analyzed, and 20 of them met the specifications of ISO 7730/2005, while two did not meet. This means that 90.90% of the evaluated environments can be considered thermally comfortable.

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7. Acknowledgement

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