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State Public Schools and Thermal Comfort: *The Case of Eemti Monsenhor José Gerardo Ferreira Gomes in the City of Sobral (CE) – Brazil*

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Abstract

This article aims to analyze the thermal comfort of the courtyard/cafeteria of the Monsenhor José Gerardo Ferreira Gomes Full-Time High School (EEMTI), from the perspective of the Disconfort Index (DI). The research was guided by the theoretical assumptions defined by Professor Carlos Augusto de Figueiredo Monteiro (2003), who defined a theoretical and methodological framework for the understanding of the urban factor, through the Urban Climate System (UCS). The aforementioned school, located on the outskirts of the city of Sobral/CE-Brazil, underwent changes in its teaching modality in 2017, changing to the full-time education system, where students remain at school all day, eating three meals. However, the building, even though it has undergone some adaptations for this new modality, is the same as when it was inaugurated in 1977. This fact, associated with the local environmental conditions of hot semarid climate, typical of the Brazilian Northeast, makes it difficult for students to accommodate and remain in outdoor spaces. The results collected and the DI analysis indicate a situation of thermal discomfort in most of the times analyzed, even though the research took place in the rainy season for the region, which presents a lot of cloudiness and milder temperature conditions.

Keywords: School of Basic Education, thermal comfort, Semiarid region of Northeast Brazil

1. Introduction and Contextualization

According to the ONU document called "Agenda 2030 – Brazil", in countries such as Brazil, due to social inequalities and socio-spatial segregation, environmental impacts and their consequences are processed in a differentiated way, where the poorest segments of urban society become more vulnerable to extreme natural events and the socio-environmental risks derived from such events.

Monteiro (1976, 2003) states that, since the city is the "dwelling place of man", all its relations of organization, building, functions and services are architected in a morphological structure, geoecological characteristics and its own climatic dynamics, culminating in an Urban Climate System (UCS). Therefore, each city has its own climate, which results from the action of all the elements and factors that permeate the urban environment , altering the climate on a local scale.

The UCS is one of the bases that constitutes the methodological framework used in this research, more specifically the conceptual basis of the perception systems of Channel I, the thermodynamics. The perception channel of thermal comfort encompasses the components derived from heat, winds and humidity, and affects everyone constantly, mainly due to the context of global warming, already evidenced and debated by scientists and media around the world.

According to the ONU (2019), 55% of the world's population lives in cities, while in Brazil this figure is even higher, 84% according to IBGE data (2010). As in Brazil, a large part of the world's population lives in the so-called intertropical zone, in addition to this natural issue, another fundamental factor is that this population is concentrated in the urban areas of poor countries or so-called "developing" countries (United Nations, 2015).

It can be seen that the production of urban space, obeying capitalist reproduction, generates socio-spatial segregation and does not produce a system that respects and/or adapts to natural conditions. These contradictions are reflected in the form of impacts between social groups, with spaces and groups always being more vulnerable to climate action (Sant'Anna Neto, 2012).

From this perspective, peripheral neighborhoods, especially in poor and emerging/developing countries, concentrate a large part of the socio-environmental problems of cities. Social problems that have intensified in recent years, especially violence and illicit drug trafficking, thus, the school expands its role of importance to society, especially with the expansion of full-time schools, as has been happening in Brazil, including the State of Ceará, especially after the year 2017.

Until 2015, in Brazil, there was no consolidated national policy aimed at implementing a system of full permanence of students in school. The students remained in school only one shift, morning or afternoon, which aggravated the social situation of children and adolescents in areas of poverty, who were more exposed to hunger, insecurity and the enticement of criminals.

The Brazilian policy of expanding full-time education is based on the assumptions of converting a one-shift school, morning or afternoon, to a full-time school, according to goal 6 of the National Education Plan (PNE) of the Ministry of Education (MEC).

The full-time school has in its guidelines to be welcoming, providing children and adolescents with a safe environment full of learning opportunities and cultural and recreational experiences. When they are located in socioeconomically vulnerable communities, susceptible to socio-environmental risks and food insecurity, they play the role of safeguarding students from exposure to violence and lack of daily food, keeping them in a condition favorable to their human development for two shifts.

In this context, the state of Ceará, the federative unit of Brazil in which the school studied in this research is located, is one of the states that has been standing out nationally.

According to the Department of Education of the State of Ceará - SEDUC/CE (Ceará, 2024) the Full-Time High School (EEMTI) is conceived as a learning community, that is, students, school and community establish common goals and implement actions based on scientific evidence and lived reality to achieve maximum learning and improve coexistence among all. To this end, State Law No. 16,287, of July 20, 2017, was approved, and goal 6 of the State Education Plan (PEE) was also established, as indicated by the National Education Plan.

However, in Ceará, the process of conversion of old schools, originally built for the permanence of only one shift, into full-time schools, has been problematic due to several aspects, among them, the aspect related to thermal comfort, especially in schools far from the coast, located in the interior of Ceará, which have a hot semiarid climate, as is the case of the city of Sobral. where the EEMTI Monsenhor José Gerardo Ferreira Gomes school is located (Figure 1).

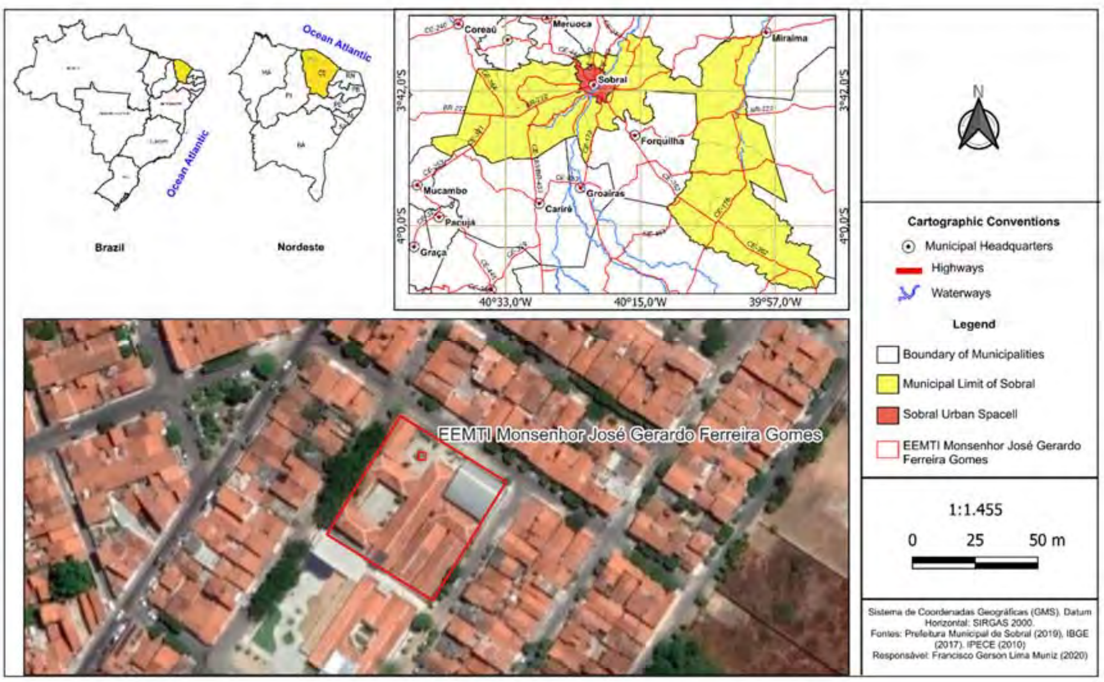


Figure 1. Location of EEMTI Monsenhor José Gerardo Ferreira Gomes

Source: Prepared by the authors.

According to Caracristi (2000, 2014), the city of Sobral, located at 30 41' south latitude and 400 west longitude, in the northwest of Ceará (Ceará – Brazil), has a hot tropical semiarid climate, with severe drought, between 7 and 8 months of water deficiency (Figure 2), with an average annual rainfall of around 500 to 800 mm (Figure 3). Temperatures are high all year round, with an annual average of 28°C (Figure 4). 20'

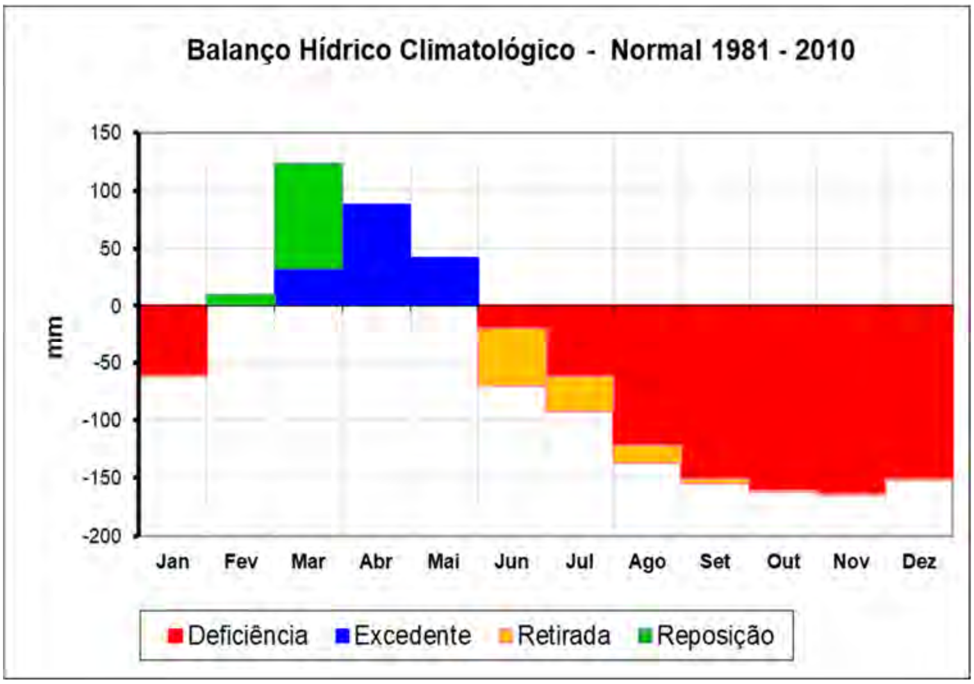


Figure 2. Water balance of Sobral/CE between 1961 and 1990

Source: Prepared by the author based on INMET data.

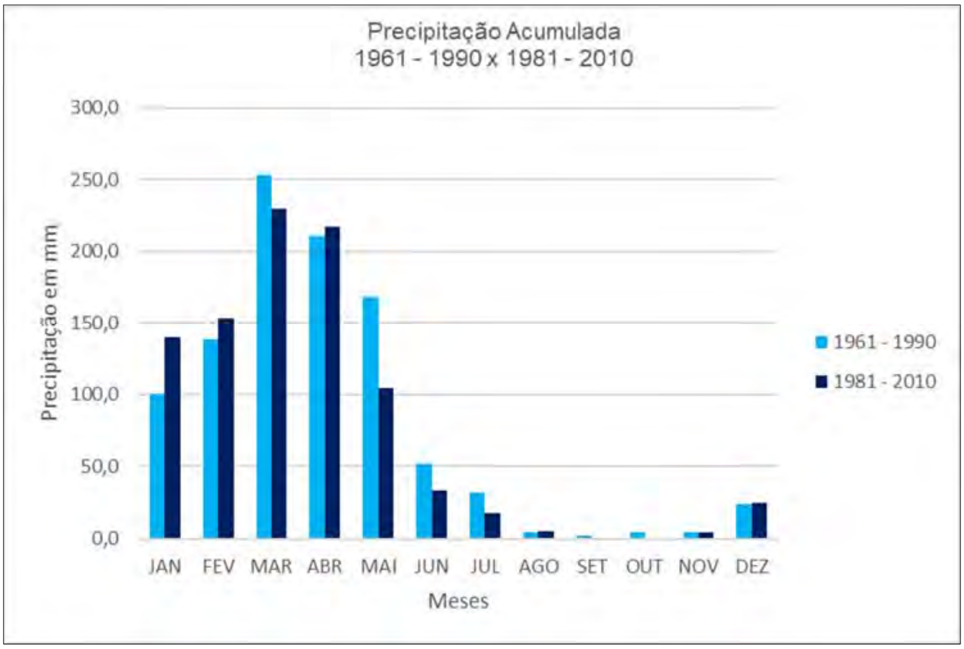
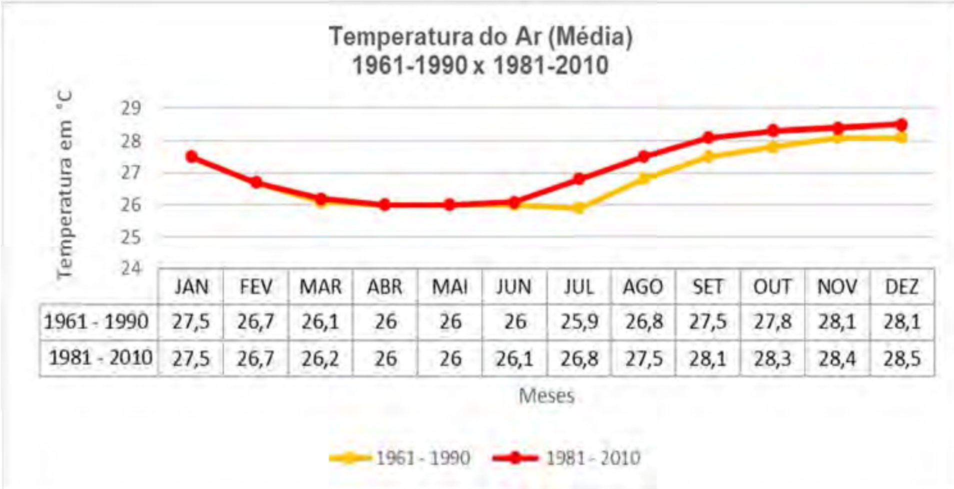


Figure 3. Climatological Normals of Precipitation in Sobral/CE

Source: Prepared by the author based on INMET data.



	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1961 - 1990	27,5	26,7	26,1	26	26	26	25,9	26,8	27,5	27,8	28,1	28,1
1981 - 2010	27,5	26,7	26,2	26	26	26,1	26,8	27,5	28,1	28,3	28,4	28,5

Figure 4. Average air temperature in Sobral/CE between 1961–1990 and 1981–2010

Source: Prepared by the author based on INMET data.

This environmental condition of semiaridity associated with low altitudes (average altitude around 70 m) and intense deforestation around the city, cause thermal discomfort throughout the year, especially in the second half of the year (Figure 5), when the dry season occurs (Muniz & Caracristi, 2018, 2023).

	PCD 3 – Praça de Cuba								
	DISCONFORT INDEX								
	DIA DO MÊS/DIA DA SEMANA								
	14/QA	15/QU	16/SX	17/SB	18/DO	19/SE	20/TE	21/QA	22/QU
00:00	24,31	24,15	25,07	24,43	24,74	24,68	24,33	24,42	25,33
01:00	24,11	24,06	25,12	24,17	24,56	24,56	24,24	24,37	25,64
02:00	23,97	24,06	25,12	24,04	24,34	24,56	24,00	24,26	25,31
03:00	23,77	23,96	25,20	23,86	24,52	24,50	23,78	24,05	25,44
04:00	23,38	23,96	25,10	23,66	24,43	24,94	23,70	23,34	25,58
05:00	23,13	24,23	24,92	22,93	24,55	24,68	23,62	23,18	25,54
06:00	23,32	24,51	25,22	23,16	24,79	25,00	23,88	23,55	25,65
07:00	26,58	26,65	26,63	26,64	26,06	26,23	26,62	26,69	26,39
08:00	26,29	26,84	27,00	26,39	26,75	27,33	26,22	26,38	26,94
09:00	26,97	27,42	26,79	25,78	27,72	27,53	27,10	26,85	27,26
10:00	27,12	28,29	27,67	27,13	27,68	27,82	26,62	27,57	28,10
11:00	27,51	28,26	28,44	28,46	28,10	27,48	27,99	27,71	28,14
12:00	28,34	28,22	28,47	28,45	28,34	27,92	28,57	28,25	28,43
13:00	28,30	28,37	28,35	28,91	28,25	28,46	28,93	28,49	29,22
14:00	28,25	28,78	28,59	28,42	28,17	28,53	28,80	28,60	28,83
15:00	27,81	28,76	28,21	28,90	28,19	29,01	28,27	29,02	29,58
16:00	28,03	28,56	28,81	28,93	28,18	28,37	28,35	28,66	28,89
17:00	27,05	27,55	27,41	27,63	26,68	27,05	26,81	27,73	26,96
18:00	26,03	26,54	26,13	26,33	25,71	25,65	25,91	27,00	26,35
19:00	25,74	26,59	25,58	25,99	25,80	25,54	25,81	26,16	26,51
20:00	25,20	25,90	24,99	25,45	25,23	25,17	25,12	26,03	26,00
21:00	24,73	25,40	24,72	25,24	24,99	24,91	24,72	25,64	25,46
22:00	24,44	25,26	24,67	25,17	24,87	24,66	24,59	25,51	25,27
23:00	24,30	25,10	24,53	24,95	24,81	24,51	24,55	25,48	25,02

	PCD 3 – Praça de Cuba								
	DISCONFORT INDEX								
	DIA DO MÊS/DIA DA SEMANA								
	14/QA	15/QU	16/SX	17/SB	18/DO	19/SE	20/TE	21/QA	22/QU
00:00	25,35	25,20	24,59	24,56	24,93	25,08	24,00	24,43	25,35
01:00	24,94	25,10	24,42	24,17	24,63	24,88	23,45	24,24	25,39
02:00	24,65	24,88	23,99	24,30	24,43	24,57	23,10	24,44	24,73
03:00	24,42	24,46	23,51	23,64	24,28	24,54	23,13	24,34	24,45
04:00	24,25	24,60	23,30	23,51	24,24	24,62	22,96	24,29	23,99
05:00	23,97	24,65	23,29	23,27	23,81	24,38	22,98	24,12	24,00
06:00	23,88	25,08	23,44	23,26	24,22	24,38	22,87	24,12	23,26
07:00	26,71	25,36	26,05	24,85	27,73	25,86	23,75	25,62	25,11
08:00	29,47	25,97	28,43	29,00	28,82	27,87	25,93	28,45	28,64
09:00	30,21	26,96	29,11	29,45	29,79	29,42	29,64	30,42	28,64
10:00	29,43	29,21	28,91	28,90	28,51	27,95	30,87	30,59	29,51
11:00	29,72	29,99	29,57	30,24	30,22	29,43	29,91	30,22	29,14
12:00	29,76	28,40	29,48	29,64	29,21	29,22	28,97	29,99	29,24
13:00	30,71	29,62	28,94	28,92	29,11	25,62	30,07	31,23	29,80
14:00	30,75	30,67	29,88	30,01	30,40	26,60	30,06	29,78	30,38
15:00	30,66	29,42	29,42	27,09	29,27	26,74	27,73	26,89	30,26
16:00	29,03	28,80	28,41	27,55	26,41	26,61	24,77	26,21	28,84
17:00	30,90	27,86	27,57	27,45	27,04	26,38	25,11	26,43	26,72
18:00	27,45	26,78	26,61	26,59	26,11	25,31	25,03	26,04	26,03
19:00	26,78	26,60	26,35	26,11	26,22	24,67	24,60	25,69	25,17
20:00	26,46	25,08	25,95	25,87	25,95	24,37	24,46	25,56	23,62
21:00	26,11	25,08	25,58	25,54	25,57	24,52	24,80	25,72	23,68
22:00	25,80	24,97	25,25	25,11	25,10	24,41	24,84	25,56	23,70
23:00	25,52	25,31	24,90	25,02	25,14	24,10	24,59	25,53	23,72

Figure 5. Thermohygrometric discomfort for the Thom index – Praça de Cuba

Source: Prepared by the author.

Due to the climatic characteristics described above, in the aforementioned school, several complaints were registered from students and teachers regarding excessive heat in the food and recreation areas, which do not have air conditioning. Only classrooms have air-conditioners.

The thermal discomfort manifested by students and teachers demonstrates that the policy of the EEMTI's, although important, was carried out in Sobral, without the ideal conditions of adaptation to the local climate, because, in most cases, the structural and infrastructure aspects of the school buildings demonstrate adverse situations for the comfortable permanence of students all day, morning and afternoon, on the school grounds. In the specific case of EEMTI Monsignor José Gerardo Ferreira Gomes, clearly the spaces outside the classrooms cannot accommodate the number of students, in addition to the clear needs for improvements in architectural conditions that allow greater circulation of winds and heat dissipation.

This fact motivated the research group of the Laboratory of Environmental and Climate Studies (LEAC) of the Geography Course of the Vale do Acaraú State University (UVA), to carry out the present research, aiming to analyze the thermal discomfort in the spaces outside the classrooms at the EEMTI Monsenhor José Gerardo

Ferreira Gomes school, more specifically in the patio/cafeteria space. identifying its direct causes, using the technical-methodological perspective of the *Discomfort Index* (Giles et al., 1990).

2. The Full-Time Policy and the EEMTI Monsenhor José Gerardo Ferreira Gomes

The school census released in February 2024 by the Ministry of Education shows that in 2023 there were 7.7 million enrollments in Brazilian high school. Full-time secondary education, on the other hand, reached 9.9% of the public network across the country (Ceará, 2024)

The state of Ceará stands out in the full-time modality, where, according to data from the Department of Education – SEDUC (Ceará, 2023), full-time is offered in more than 70% of the schools in the state high school network, which represents the third best index in the country, in terms of the proportion of students enrolled full-time, behind the states of Pernambuco and Paraíba.

The full-time modality is a state education policy that aims at universalization,

> The Plan for the Universalization of Full-Time School in Ceará is based on conversion premises that aims to consider all Regular High Schools in the network and, based on them, define the list of schools eligible for conversion by 2024, in order to comply with Law No. 16,287, of July 20, 2017. goal 6 of the National Education Plan (PNE) and goal 6 of the State Education Plan (PEE) (Ceará, 2024).

Within this panorama, full-time schools had their first units in operation in Ceará in 2017, obeying some criteria defined by SEDUC/CE. Eligible schools should have 50% or more of the students receiving Bolsa Família (Note 1) and the school unit should have less than 60% of vacancies and the municipality should have at least two state schools. And as a prioritization criterion 1 of the school by region (Crede/Sefor): infrastructure conditions and low approval rate.

And it is in this educational composition that we arrive at the EEMTI Monsenhor José Gerardo Ferreira Gomes – MJG (Figure 6), located in the city of Sobral, more precisely in the Cohab I neighborhood, in the southwest portion of the city.

Figure 6. Facade of the EEMTI Monsenhor José Gerardo Ferreira Gomes School – MJG

Source: Prepared by the authors.

Founded on March 9, 1977, throughout its history the school has met local demands and the educational legislation of each government period. In 2017, the school adopted the full-time regime, completing the cycle in 2019, and since then it is the only modality existing in the school.

Currently the school consists of 12 classrooms, 01 computer lab; 01 Science Laboratory; secretariat; canteen/kitchen; men's and women's restrooms; 02 warehouses; Specialized School Service (AEE) room; teachers' room; and 02 mini-sports courts, one of which is covered.

Over these more than four decades, there have been some transformations and adaptations of buildings and infrastructure, but the main building is the same. For full-time, the most significant changes were only due to the expansion of the bathrooms and kitchen.

The Full-Time school offers 3 meals throughout the day, so it requires a structure to feed the students, which goes from the kitchen to the cafeteria, but the MJG school does not have the structure for this, so it transformed the courtyard into a cafeteria, which cannot contemplate the universe of full-time students, which in the year 2023 was 385 students, divided into 10 classes.

The MJG serves students from 5 neighborhoods around it (Figure 7), popularly known as the great Sinhá Sabóia, but comprises the neighborhoods, Sinhá Sabóia, Cohab I, Cohab II, Jatobá and Cidade Dr. Gerardo Cristino de Menezes, all characterized by high social vulnerability (Chart 01).

Figure 7. Neighborhoods served by EEMTI Monsenhor José Gerardo Ferreira Gomes

Source: Google Earth, 2024.

Table 1. Profile of the Neighborhoods and Communities in the CadÚnico (Single Registry for Social Programs of the Federal Government) served by the EEMTI Monsenhor José Gerardo Ferreira Gomes

Neighborhoods	Families registered with CADÚNICO	Families assisted by the Bolsa Família Program (PBF)	Families in Extreme Poverty	Extreme Poverty Families with PBF	Extreme Poverty Families without PBF
Cohab II	1429	613	455	403	52
Sinhá Sabóia	1175	467	381	332	49
Cidade Gerardo Cristino de Menezes	1096	578	468	427	41
Cohab I	260	73	58	51	7
Jatobá	0	-	-	-	-

Source: Prepared by the authors, based on Muniz (2023), SEDHAS data (2020).

As can be seen in the data above, the neighborhoods served by the school are characterized by socioeconomic vulnerability and serious social problems. When we talk about land use and occupation, these are neighborhoods that have significantly grown their territories, including the arrival of housing complexes, and urban equipment, both public and private.

3. The S.C.U., Thermal Comfort and the School Environment

The Urban Climate System (UCS) is based on the dynamic conception of climate expressed by Max Sorre (1951) and on the principles of the General Systems Theory (GST). Climate analyses can be approached at a macro, meso, and microdimensional level, targeting global, regional, intra-regional, local climate systems, and so on.

In this way, studies on natural dynamics are based on the assumptions of open systems and climatic elements are observed in their internal and external interactions:

> The S.C.U. aims to understand the peculiar climatic organization of the city and, as such, is essentially focused on the atmosphere, which is thus seen as *an operator.* All the natural ecological action and the associations with the phenomena of urbanization constitute the complex whole on which the operator acts. For this reason, everything that is not atmospheric and that materializes in the urban space, including man and other living beings, constitute elements of the system, structuring the parts that, through their reactions, define special attributes. For this reason, everything that is not atmospheric and that materializes in the urban space, including man and other living beings, constitutes elements of the system, being structured in parts that, through their reactions, define special attributes […] (Monteiro, 2003, p. 21, emphasis added).

UCS can be considered an adaptive system in which the evolution of man's decision-making power is channeled as an intervention mechanism for self-regulation (Monteiro, 2003). The UCS presupposes a general level of resolution that is the climate of the city itself, but admits levels of resolution that characterize the subsystems it contains (Monteiro, 2003).

Based on these premises, Monteiro (2003) elaborates a theoretical-methodological framework (Table 2), illustrating these levels of resolution and functional hierarchies, named "The Channels of Perception". These levels form the general structure of the SCU and are composed of three subsystems: a) Thermodynamic subsystem: thermal comfort channel; b) Physicochemical subsystem: air quality channel and; c) Hydrometeoric subsystem: meteoric impact channel.

Table 2. Urban Climate System – Articulations of the subsystems according to the channels of perception

CHARACTERIZATION	**SUBSYSTEMS**		
	Thermodynamic	**Physical - chemical**	**Hydrometeoric**
	PERCEPTION CHANNELS		
	I **Thermal comfort**	**II** **Air quality**	**III** **Meteoric impact**
Source	Atmosphere Radiation Horizontal Circulation	Activities Urban Motor Vehicles Industrial Cleaning works	Atmosphere Special States (rhythmic deviations)
Transit in the system	Operator and operand exchange	From operator to operator	From operator to operator
Mechanism of action	Transformation in the system	Diffusion through the system	Concentration on the system
Projection	Core Environment Interaction	From the core to the environment	From the environment to the core
Development	Continuous (permanent)	Cumulative (renewable)	Episode (eventual)
Observation	Special Weather (fieldwork)	Special sanitary and meteorological	Weather Hydrologic (fieldwork)
Correlations Disciplinary and Technological	Bioclimatology Architecture Urbanism	Sanitary engineering	Sanitary Engineering and Urban Infrastructure
Products	"Heat islands" Ventilation Increased precipitation	Air Pollution	Attacks on urban integrity
Direct effects	Discomfort and reduction in human performance	Health problems	Circulation problems
Recycling Adaptive	Land use control Housing comfort technology	Surveillance and control of pollution agents	Improvement of urban infrastructure and river regulation Land use
Responsibility	Nature and man	Man	Nature

Source: Monteiro, 2003.

According to Monteiro (2015, p. 98), thermal comfort is one of the channels of human perception of the climate, a “very significant perceptual filter” encompassing the thermodynamic components that are expressed through heat, ventilation, and humidity. Thermal comfort is an important factor in urban environmental quality. Together with other cultural and socioeconomic variables, biological-physiological and psychological variables are part of a set of parameters that define environmental comfort (Frota & Schiffer, 2001). Thus, elements of the climate, such as temperature, humidity and winds, should be associated, for example, with variables such as metabolic and physical activities, heat loss/sweat rate, steam saturation tension, among others.

Climate perception is also strongly influenced by personal physiological conditions (age, sex, body mass, chronic diseases, and metabolism). Another important aspect related to thermal comfort is the ways to prevent uncomfortable situations, for example, through appropriate clothing, construction material for homes, and equipment for heating or cooling spaces (Muniz & Caracristi, 2019).

Three approaches are presented by several authors in relation to the study of thermal comfort: subjectivity, physiological reactions and the environment. Subjectivity is associated with individual thermal perceptions and preferences. The approach that considers physiological factors refers to the body’s reactions, such as body temperature, epidermis reactions, blood flow, sweat rate, among others. These reactions are closely linked to metabolism (age, sex, body mass) and are influenced by individual clothing. Finally, the approach to the environment takes into account the elements of climate: temperature, humidity, atmospheric pressure, wind, radiation. It is important to note that the performance of these elements differs according to the type of construction material of the buildings in which people are sheltered.

The analysis of thermal comfort, although performed through different approaches, is not always conclusive or easy to understand. Moura, Sales and Zanella (2010, p. 178) used several authors and sought an approximation between these approaches, defining the variables of thermal comfort by means of three specific indices:

> According to Frota and Schiffer (1988), Santana (2002), Hissa (2000) and Buriol et al. (2004), the analysis of climatic comfort occurs through indices that are classified into different aspects such as: 1) biophysical indices, which are based on the heat exchanges between the body and the environment, correlating the elements of comfort with the heat exchanges that give rise to these elements; 2) physiological indices, which are based on the physiological reactions originated by known conditions of dry air temperature, mean radiant temperature, air humidity and wind speed and 3) subjective indices, which are based on the subjective sensations of comfort experienced under conditions in which the elements of thermal comfort vary.

The variables that determine the biophysical indexes, with great importance to determine the different comfort ranges, are temperature, relative humidity, air and wind speed. For Frota and Schiffer (2001, p.15), these elements are “closely related to rainfall regimes, vegetation, soil permeability, surface and groundwater, topography, among other local characteristics that can be altered by human presence.”

According to Monteiro (2013, p. 155), when there is no thermal neutrality “[…] The human being begins to feel discomfort and discomfort, and may even die.” Thus, temperatures play a key role in the thermoregulatory balance of the human organism, which, due to its homeothermic character, requires a body temperature close to 37°C (Frota & Schiffer, 2001). Thus, if the average temperature of the environment is higher than the temperature of the human body, it will receive heat by radiation. On the other hand, if the ambient temperature is lower than the body temperature, the body will lose heat through radiation (Souza & Nery, 2012).

Although it can generate discomfort in cold situations, in cities with a very hot climate, as is the case of Sobral, most of the time, the wind mitigates the heat. In addition to the intensity, it is also necessary to pay attention to the direction of the wind, especially in the urban context, since this meteorological variable influences and is influenced by other elements, acting on processes of heat transport (convection) and humidity (evaporation), as well as on the dispersion of pollution (Souza & Nery, 2012).

Regarding the physiological indexes, the human organism experiences the sensation of thermal comfort when it loses energy to the environment without resorting to any thermoregulation mechanism, that is, the heat produced by the metabolism is compatible with its activity (Frota & Schiffer, 2001). The highest efficiency of the human body is at a temperature of 37°C, with very narrow limits — between 36.1 and 37.2°C — with 32°C being the lower limit and 42°C being the upper limit for survival (Ayoade, 2003; Fleet & Schiffer, 2001).

Metabolism, the main process related to the physiological index, consists of a “set of all biochemical processes involved in the maintenance of the life of a being” (Glossary of Biology and Sciences, *online*). Among these processes is the transformation of food into energy to carry out daily activities. In order for there to be comfort, thermal neutrality is necessary, which occurs when the human body is at a temperature close to 37°C; otherwise, the individual may experience cold or heat stress.

Although metabolism is inherent to the human body, there are individual conditions that accelerate or slow down these biochemical processes, such as gender, age, body mass, fat, eating habits, and health states (Fante, 2019). In addition to individual characteristics, particular habits also interfere with metabolism. This is the case of acclimatization, according to which "individuals are able to adapt their habits and metabolic changes depending on the climatic context" (Fante, 2019, p 82).

In adverse weather situations, such as the one that characterizes our study area, semiarid tropical climate, the type of fabric, size and colors influence the body's perspiration and interfere with the process of absorption or reflection of solar energy.

Finally, the subjective index considers the individual's perception of the feeling of comfort. Fante (2019) proposes that this perception is based on experiences already lived, as well as individual and cultural preferences. In practical terms, inhabitants who experience a semiarid tropical climate tend to be more uncomfortable with the cold than people who are used to a humid subtropical climate.

We can see that thermal comfort plays a fundamental role in human behavior, especially when we talk about the teaching-learning process. Schiff and Somjen (1985) stated that the increase in temperature compromises the functioning of neurons, thus affecting physiological and behavioral performance. Frota and Schiffer (2001) reinforce the previous statement when they report that the increase in temperature from 20º C to 30ºC of ambient temperature causes a 28% reduction in school performance.

It is worth mentioning that the MJG school environment to be evaluated is the environment outside the classrooms, more precisely the courtyard that was transformed into a cafeteria. The classrooms have artificial air conditioning, with air conditioners. It is emphasized that the building is old, with several adaptations and there is no air circulation and the external area is small for the number of students who use it during breaks and lunch period.

The thermal (un)comfort indices allow an objective assessment of comfort based on categorization. There are several indexes. However, we chose to highlight only the one that subsidized the research. According to Fante (2019), this index varies according to different studies, differing, above all, in terms of equations and characteristics.

The original Thom Discomfort Index equations were based on dry and wet bulb temperatures, the former in ºC and the latter in ºF (Equations 1 and 2):

$$\mathbf{DI = 0{,}4.\ (T_d+T_w)+4{,}8} \quad (1)$$

Wich,

DI → Discomfort Index

Td → Dry bulb temperature (ºC)

Tw → Wet Bulb temperature (ºC)

Obs.: Temperatures with simultaneous readings (Ayoade, 2003).

$$\mathbf{DI = 0{,}4.(T_d+T_w)+15} \quad (2)$$

Onde,

DI → Discomfort Index

Td → Dry bulb temperature (ºF)

Tw → Wet Bulb Temperature (ºF)

Note: Temperatures with simultaneous readings (Ayoade, 2003).

This index has been used to observe the range of comfort for clothed and resting adults, establishing temperatures between 18.9 °C and 25.6 °C as a comfort zone. Values lower or higher than this range indicate stress to cold and heat, respectively (Ayoade, 2003).

However, in order to achieve the objectives of the research and in accordance with the variants of thermal comfort studied, we chose to use the equation proposed by Giles et al. (1990), in which the authors use the relative humidity in % to replace the wet-bulb temperature (Equation 3). Despite appearing with different nomenclatures, this index was also adopted by Gobo (2013), Funari (2006) and Pereira, Aleixo and Silva-Neto (2016).

$$\mathbf{DI = Td-0{,}55.(1-0{,}01.RH).(Td-14{,}5)} \quad (3)$$

Wich,

DI → *Discomfort Index*

Td → Dry bulb temperature (ºC)

RH → Relative humidity (%)

Note: Temperatures and relative humidity with simultaneous readings (Giles et al., 1990, p. 102). In this study, we present the results followed by °C/ID. For example, if the index result is 30, we will show 30°C/ID.

4. Methodological Procedures

The urban climate of Sobral is being considered based on the method of Rhythmic Analysis of Monteiro's SCU (1971, 2003), valuing the atmospheric dynamism, more specifically the thermodynamic subsystem, in its microclimatic scale, which has as one of its perceptions the thermal comfort, which varies at the individual physiological and psychological level, and the social level. plays a crucial role in this perception.

Based on the aforementioned theoretical-methodological assumptions of Monteiro (2003) and the technical application of the *Discomfort Index*, primary data on air temperature and relative humidity of the school were produced in the seasonality of the rainy season. The valid data for the research correspond to school days 12, 13, 14, 17 and 18 April 2023, in the austral autumn (Figure 8).

Figure 8. Courtyard/Refectory of EEMTI Monsignor José Gerardo Ferreira Gomes

Source: Personal archive, 2023.

We used a *datalogger* (Figure 9), located in microclimatic PVC (polyvinyl chloride) shelters, 1.5 m from the ground, following the specifications of Castelhano and Roseghini (2011) (Figure 10). The shelter consists of material that is easy to handle and has a lower financial cost compared to the standard INMET (National Institute of Meteorology) weather shelter. Muniz and Caracristi (2023) expose the validity and effectiveness of the PVC shelter, where the results were within the margin of error of the device, when compared to official data from the National Institute of Meteorology (INMET).

The *dataloggers* remained in the school's courtyard/cafeteria, collecting data over 7 uninterrupted days and recording air temperature and relative humidity data every 10 minutes from 7 a.m. to 4 p.m. from April 12 to 18, 2023.

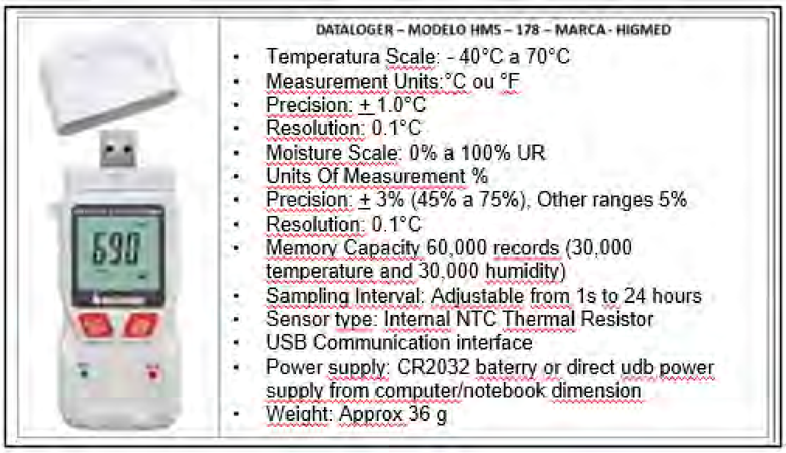


Figure 9. Thermo-hygrometer datalogger

Source: Prepared by the authors.

To analyze thermal comfort, we used Thom's thermal comfort index or *Discomfort Index* (DI), and it was based on the interval classification used by Funari (2006) and Pereira, Aleixo, and Silva-Neto (2019), which have thermal comfort classes, with coverage limits varying by almost 9°C/ID (Chart 3). The choice of this index is also justified by the fact that it admits three heat intervals, adapting to the semiarid reality.

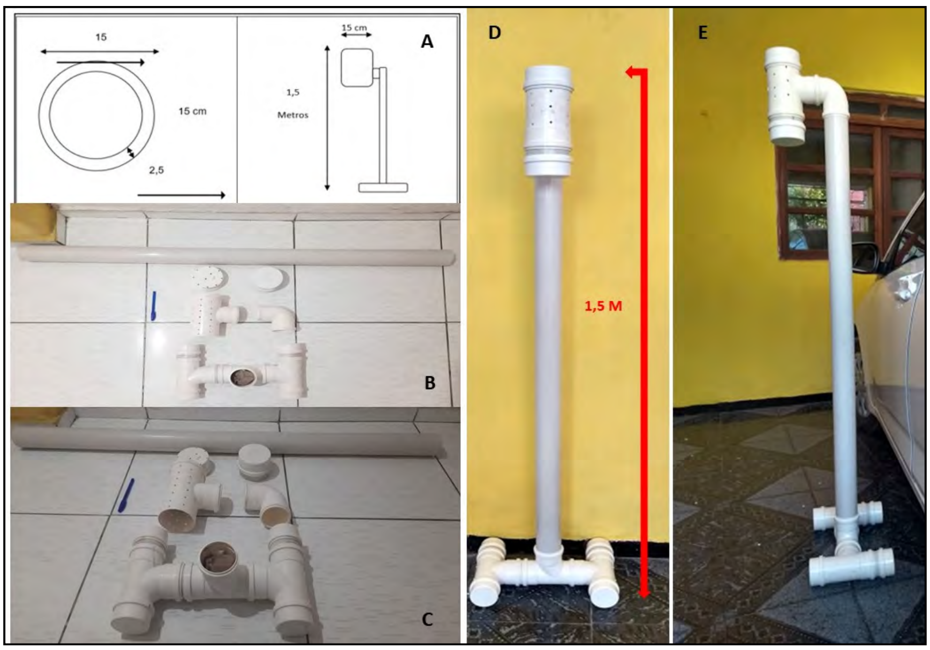


Figure 10. Steps for assembling the microclimatic shelter

Source: Prepared by the author based on Castilian and Roseghini (2011).

Table 3. Thermo-hygrometric discomfort classes for Thom's index

Index Value (°C /DI)	Features	Legend
≤ 5,9	Very high cooling	
6,0 a 8,9	High cooling	
9,0 a 11,9	Cold	
12,0 a 14,9	Discomfort in the cold	
15,0 a 17,9	Slight discomfort in the cold	
18,0 a 20,9	Lower limit of the comfort zone	
21,0 a 23,9	Center of the comfort zone	
24,0 a 26,9	Upper limit of the comfort zone	
27,0 a 29,9	Slight discomfort in the heat	
30,0 a 32,9	Discomfort in the heat	
≥ 33	High heating	

Source: Prepared by the authors, based on Silva and Souza (2017) and Funari (2006).

The data were selected and processed using *Word* 2019 and *Excel* 2019. Based on Thom's temperature and humidity index and using the equation presented by Giles et al. (1990). Equation 3 (DI = Td-0.55) was used. (1-0.01.RH). (Td-14.5) in the Excel 2019 formula bar, where Td corresponds to the temperature data and the RH to the humidity data, both collected by *the dataloggers*. In this way, we arrived at the DI values (Appendix A) and later inserted them in Chart 2, corresponding to the values and colors in each DI scale. Soon after, Frames 3, 4 and 5 were made.

The results were analyzed in 4 interstices. First, to understand the elements of the climate throughout the school day (7 am to 4 pm) and the dynamics of the school day. The second is recess in the morning, which takes place from 9:10 a.m. to 9:30 a.m., where there is a large concentration of students in the courtyard/cafeteria. The third moment is the lunch break (12 pm to 1 pm), where all students occupy the cafeteria space for lunch, that is, almost 100% of the public occupies this space during this break. And the last moment analyzed is the afternoon break (2:40 pm to 3 pm), which is usually one of the hottest times in the city of Sobral.

5. Results and Discussions

Inserted in the Brazilian Northeast (NEB), the city of Sobral does not diverge from its regional climatic characteristics, especially considering the thermodynamic analyses. Regarding the studies of the city's climate, the pioneering works were presented by Professor Isorlanda Caracristi (2000).

In the general context, as previously described, the climatic attributes are high temperatures all year round, with a high rate of insolation (2,800 hours of annual solar brightness) and with a *deficit* in its water balance during 7 to 8 months of the year. According to the classification of Köppen and Gaussen apud Caracristi, (2000), the climatic types are BSw'h and 4aTh, respectively: hot and semiarid climate with severe drought.

According to the Ceará Foundation of Meteorology and Water Resources (FUNCEME), considering the Climatological Normals (NC) of INMET (1961-1990/1981-2010), the city of Sobral presents, historically, milder temperatures in the months of April and May. As the months advance throughout the year, temperatures rise, reaching an average of more than 28°, during the months of September to December, a period known for high temperatures (Muniz & Caracristi , 2023).

In this way, we collected data in the austral autumn, considered the rainy season in the region, where the climatic conditions produce less thermal discomfort, due to greater cloudiness (Muniz & Caracristi , 2021). Remembering that, in the rainy season of 2023, the main atmospheric system that generates precipitation and humidity, the Intertropical Convergence Zone (ITCZ), was not so active on the days of the survey, with only light drizzle throughout the days, and a rain with greater intensity after 2 pm on April 18, 2023, when looking at the satellite images (Figure 11), we observe this reality.

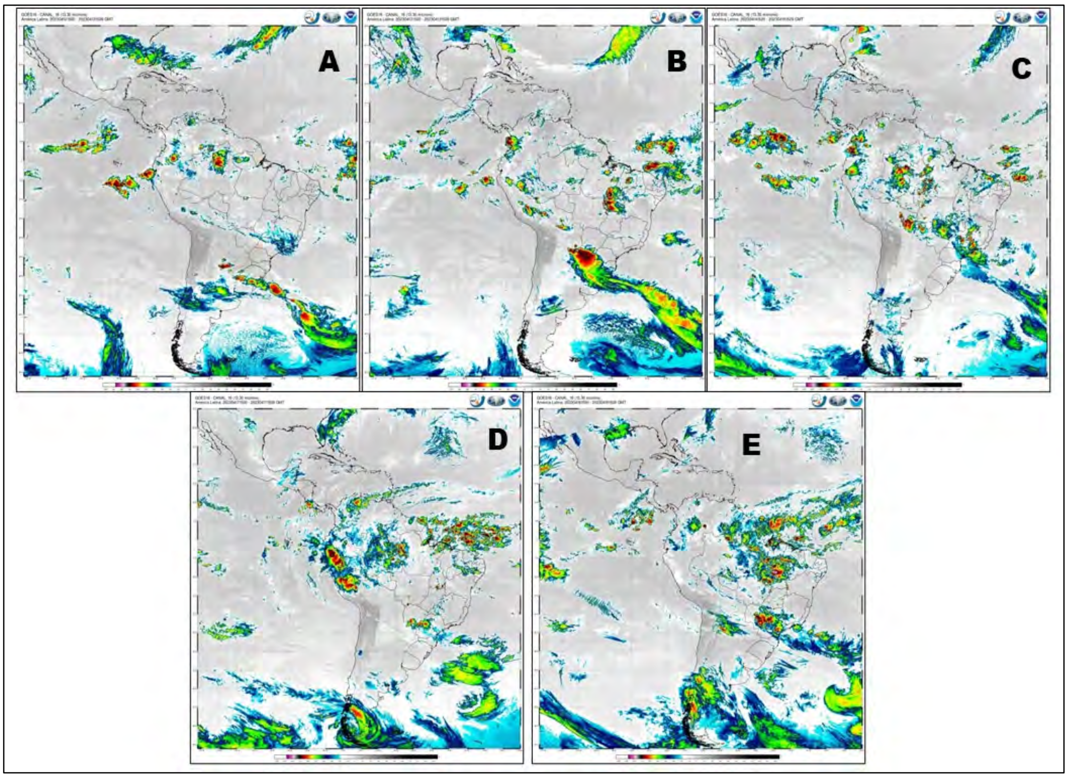


Figure 11. Image Goes 16, days 12, 13, 14, 17 and 18/04/2023, respectively A, B, C, D and E, at 12 pm (local)

Source: Prepared by the authors using images from CPTEC/INPE (2023).

Although the atmospheric conditions were favorable to milder temperatures, the results indicated high temperatures at times and unfavorable conditions for thermal comfort in the spaces outside the classrooms. The universe of people for the days of collections were 301, 294, 275, 279 and 296 students for April 12, 13, 14, 17 and 18, 2023, respectively.

Figure 12 indicates that the day with the highest temperatures was the first day of the collection (day 12), with an average of 31.5º C for the period analyzed, reaching temperatures above 35ºC at 2 pm. On this day, the first collection of the day, at 7 am, registered above 28ºC, while on the following days the records were between 24.2ºC and 26.6ºC.

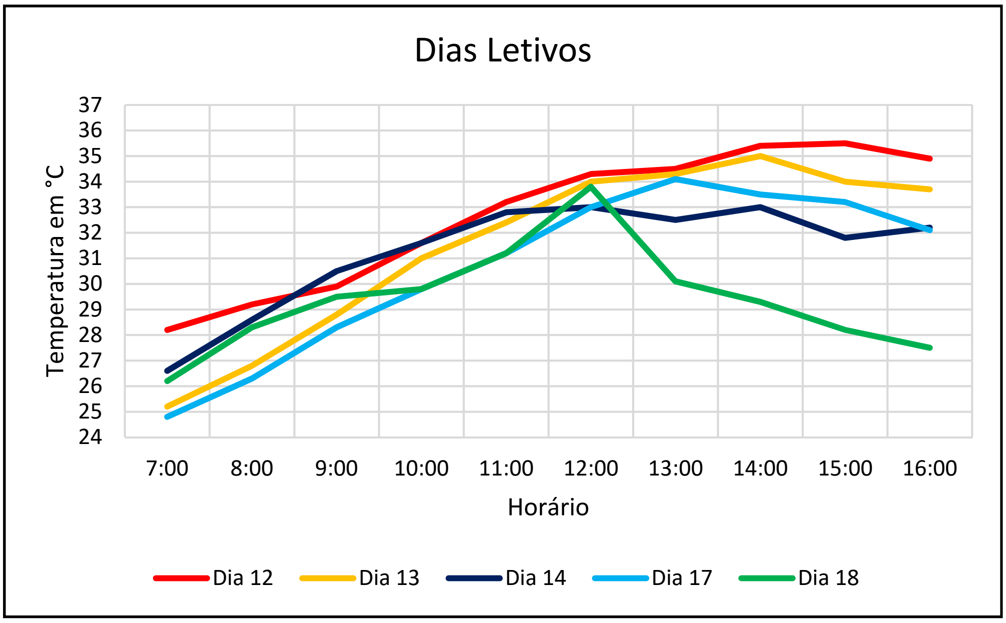


Figure 12. Air temperature for school days 12, 13, 14, 17 and 18/04/2023

Source: Prepared by the authors (2023).

The 18th, in addition to the lowest average (26.8ºC), had the lowest temperatures in the afternoon, where it did not exceed 30ºC after 1 pm. We highlight here the performance of the ITCZ that produced many clouds, humidity and precipitation. This situation is directly reflected in the relative humidity of the air (URA), and Figure 13 below indicates a significant increase in this interstice for the day in question.

The 18th also had the highest average relative humidity, with 83.4%, while the 12th had the lowest average with 54.3%. The other days, on the other hand, varied between 66% and 76%. Note that these are values that characterize the action of clouds and precipitation, which could be a favorable situation for thermal comfort. However, the absence of adequate ventilation and high temperatures indicate muggy sensations, which can generate thermal discomfort.

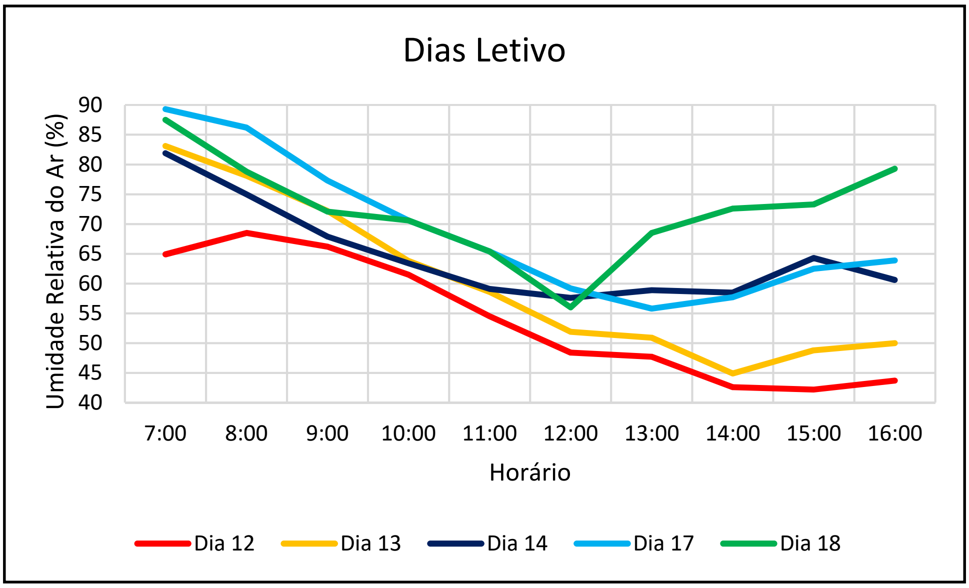


Figure 13. Relative humidity on school days 12, 13, 14, 17 and 18/04/2023

Fonte: Elaborado pelos autores (2023).

The following tables present the results on thermal comfort in the school's courtyard/cafeteria space, which were calculated from the data of air temperature (ºC) and air humidity (%) (See Appendix A) and by applying the equation DI = Td-0.55. (1-0.01.RH). (Td-14.5), programmed in the EXCEL 2019 software, generating the Discomfort Index (DI) classes. The classes found were: Upper limit of the comfort zone and mild discomfort in the heat, according to chart 3

In this first interstice of observation, which comprises the hours of the school days from 7 am to 4 pm. Chart 4 shows a variation in two stages, the upper limit of the comfort zone and the Slight discomfort to the heat. In the first hours of the beginning of classroom activities (7:30 am) there is still a pleasant environment, where even the earth's surface is already completely heated, the combination of air temperature and IVR provides thermal comfort to those who are present in the courtyard/cafeteria, however, the flow of people at these times is minimal.

Table 4. Analysis of ID for school days 12, 13, 14, 17 and 18/03/2023

Analysis - School Day					
Hour	**DI 12/04**	**DI 13/04**	**DI 14/04**	**DI 17/04**	**DI 18/04**
07:00					
08:00					
09:00					
10:00					
11:00					
12:00					
13:00					
14:00					
15:00					
16:00					

Source: Prepared by the authors (2023).

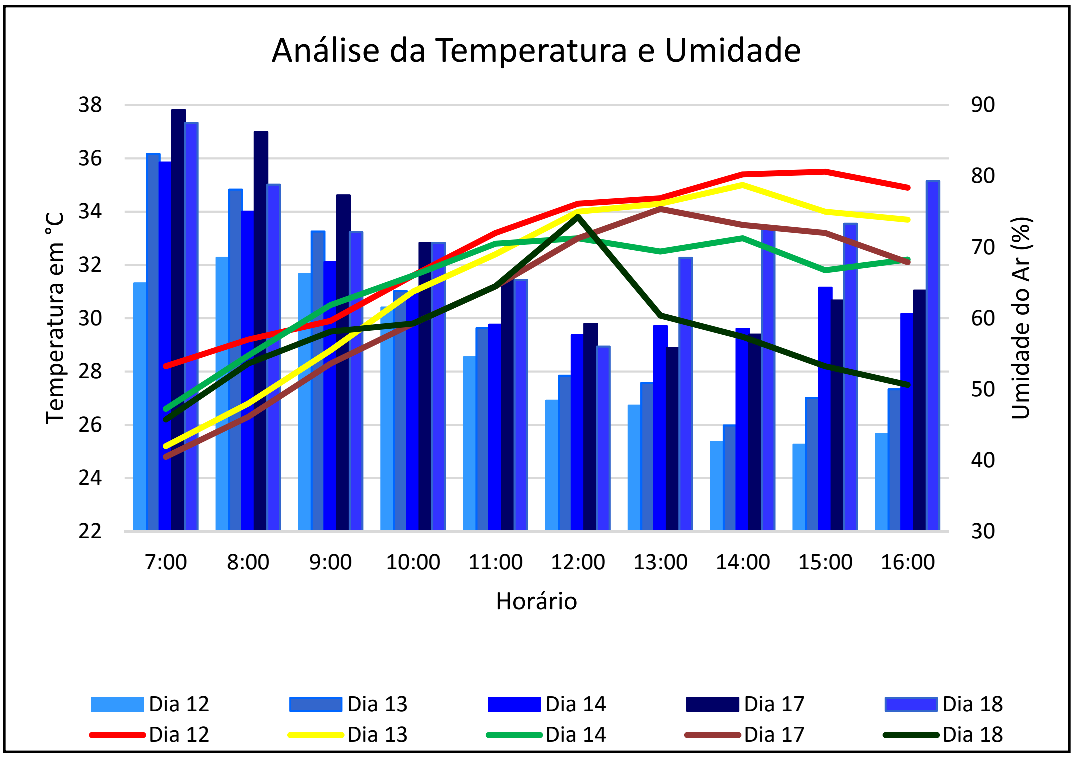


Figure 14. Relative humidity on school days 12, 13, 14, 17 and 18/04/2023

Source: Prepared by the authors (2023).

After 9 a.m., the situation of the upper limit of the comfort zone evolves to a slight discomfort in the heat, and this stage remains until the students are released at 4:35 p.m. However, as the hours progress, there is an increase in temperature and a decrease in the IVR (Figure 14), which increases the feeling of discomfort for those who occupy/transit the space. The exception occurs precisely with the presence of precipitation and increased cloudiness, causing the air temperature to decrease, a situation present at 3 pm and 4 pm, on the 18th.

When the analyses turn to the intervals throughout the day, it is seen that every 10 minutes, there is practically no variation in the *Discomfort Index* (DI) classes. The lunch break (Table 5) fixed all the times in the slight discomfort of the heat.

Table 5. Lunch break DI

Analysis - Lunch break					
Hour	**DI 12/04**	**DI 13/04**	**DI 14/04**	**DI 17/04**	**DI 18/04**
12:00					
12:10					
12:20					
12:30					
12:40					
12:50					
13:00					

Source: Prepared by the authors (2023).

The temperature variation fluctuated over the days. Day 12, the hottest day, recorded the highest temperature for the interstitium, with 34.7ºC. On the other hand, the temperature amplitude varied in tenths of a degree, where in three of the five days, an increase in temperature was observed. The highest temperature amplitude was recorded on the 17th, where between the first and the last time of the interval, the difference was 1.1ºC, going from 33ºC to 34.1ºC.

The 14th and 18th had the dynamics of a decrease in temperature after the 12 pm record, highlighting that on both days there was an increase in cloudiness and the 18th, inclusive, with light precipitation.

The morning and afternoon intervals (Table 6) showed some variations in the ID classes, however, in only 5 moments in the two interstices was the upper limit of the comfort zone observed, in the other situations, there was mild discomfort in the heat. Even in the early hours of the morning, thermal discomfort is felt by everyone who occupies and transits the patio/cafeteria.

Table 6. Morning and Afternoon break DI

Analysis - Morning Break					
Hour	**DI 12/04**	**DI 13/04**	**DI 14/04**	**DI 17/04**	**DI 18/04**
09:10					
09:20					
09:30					
Analysis - Afternoon break					
Hour	**DI 12/04**	**DI 13/04**	**DI 14/04**	**DI 17/04**	**DI 18/04**
14:40					
14:50					
15:00					

Source: Prepared by the authors (2023).

In the afternoon interval, almost entirely, discomfort is perceived in the heat, high temperatures and low IVR are predominant, the exception is precisely the 18th, due to situations of high cloudiness and precipitation.

6. Final Thoughts

Taking into account the climatic characteristics of the city of Sobral and the conditions of adaptation of the school associated with the analysis of the thermal comfort data produced, we can verify that the EEMTI Monsenhor José Gerardo Ferreira Gomes school does not have an adequate food and recreation space to provide thermal comfort to its students.

It should be noted that situations of thermal discomfort were recorded even though the data collection/production was carried out in the rainy season, where the regional climatic conditions and the local climatic elements analyzed (air temperature and relative humidity) are milder (Muniz & Caracristi , 2023) and the month of April is historically the one that has the lowest air temperatures in the city of Sobral.

When we analyzed each day of a week of school activities, we had the basis of the number of students who attended the spaces outside the classrooms (courtyard/cafeteria) at different times of the day and their routine.

We found that the school building is old, built 47 years ago, to serve students in only one shift and that in the last 6 years there have been several adaptive renovations to serve the full-time teaching of 385 students, but without considering the local climatic conditions. The renovations did not favor the circulation of winds in the spaces outside the classrooms and classrooms, so that in these spaces there is no heat dissipation, which provides thermal discomfort, especially in conditions of hotter and more humid weather and when there is a greater concentration of students.

We can infer that, if in milder temperature conditions such as in April, there was thermal discomfort, this situation will worsen, with an increase in discomfort in the period from September to December, in which the highest annual and monthly temperature averages are recorded, reaching 39°C, and has a low cloud cover.

It is essential for the well-being of students and teachers of the EEMTI Monsenhor José Gerardo Ferreira Gomes school that mitigating measures aimed at improving the thermal sensation in the patio/cafeteria spaces are taken, as it is precisely in the moments of recreation and food where there is greater integration between students and the relief of the cognitive stress of the hours in the classroom and the mitigation of the emotional impacts of the precarious social conditions in which they live the students served by the school.

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Data sharing statement

No additional data are available.

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Notes

Note 1. Income distribution program of the Brazilian federal government: financial aid aimed at low-income families/situations of socioeconomic vulnerability.

Appendix A

Air temperature (ºC) and humidity (%) data collected in the survey, and through the equation DI = Td-0.55. (1-0.01.RH). (Td-14.5), programmed in the EXCEL 2019 software, generated the results of the *Discomfort Index* (DI).

Table Appendix A. Table with data collected during the research

	Day 12			Day 13			Day 14			Day 17			Day 18		
Hora	**°C**	**%**	**DI**	**°C**	**%**	**DI**	**°C**	**%**	**DI**	**°C**	**%**	**DI**	**°C**	**%**	**DI**
07:00	28,2	64,9	25,56	25,2	83,1	25,2	26,6	81,9	26,6	24,8	89,3	24,8	26,2	87,5	26,2
08:00	29,2	68,5	26,65	26,8	78,1	26,8	28,6	75	28,6	26,3	86,2	26,3	28,3	78,8	28,3
09:00	29,9	66,2	27,04	28,8	72,2	28,8	30,5	67,9	30,5	28,3	77,3	28,3	29,5	72,1	29,5
10:00	31,6	61,5	27,98	31	63,8	31	31,6	63,4	31,6	29,8	70,6	29,8	29,8	70,6	29,8
11:00	33,2	54,5	28,52	32,4	58,6	32,4	32,8	59,1	32,8	31,2	65,4	31,2	31,2	65,4	31,2
12:00	34,3	48,4	28,68	34	51,9	34	33	57,6	33	33	59,2	33	33,8	56	33,8
13:00	34,5	47,7	28,75	34,3	50,9	34,3	32,5	58,9	32,5	34,1	55,8	34,1	30,1	68,5	30,1
14:00	35,4	42,6	28,80	35	44,9	35	33	58,5	33	33,5	57,7	33,5	29,3	72,6	29,3
15:00	35,5	42,2	28,82	34	48,8	34	31,8	64,3	31,8	33,2	62,5	33,2	28,2	73,3	28,2
16:00	34,9	43,7	28,58	33,7	50	33,7	32,2	60,6	32,2	32,1	63,9	32,1	27,5	79,3	27,5
09:10	30	66,5	27,14	29,3	71,5	29,3	30,6	67,1	30,6	28,6	76	28,6	30,1	70	30,1
09:20	30,2	66,2	27,28	29,9	69,1	29,9	30,8	66,5	30,8	28,9	75,3	28,9	30,2	69,5	30,2
09:30	30,6	64,5	27,46	30,5	67,3	30,5	31,1	65,7	31,1	29,2	73,2	29,2	30,6	68,4	30,6
12:00	34,3	48,4	28,68	34	51,9	34	33	57,6	33	33	59,2	33	33,8	56	33,8
12:10	34,3	47,6	28,59	34	52,8	34	32,8	57,9	32,8	33,4	58,5	33,4	33,5	56,2	33,5
12:20	34,5	48	28,78	34,2	52,4	34,2	32,8	58,7	32,8	33,7	56,5	33,7	33,5	56,3	33,5
12:30	34,3	47,6	28,59	34,2	51,8	34,2	32,7	59,5	32,7	33,7	56,4	33,7	33,7	56,3	33,7
12:40	34,4	47,4	28,64	34	51,8	34	32,2	60,8	32,2	33,6	56,1	33,6	33,5	56,6	33,5
12:50	34,7	46,3	28,73	34,2	51,6	34,2	32,2	59,8	32,2	34	56	34	32,5	62,9	32,5
13:00	34,5	47,7	28,75	34,3	50,9	34,3	32,5	58,9	32,5	34,1	55,8	34,1	30,1	68,5	30,1
14:40	35,5	42,2	28,82	34,7	45,9	34,7	33	58,4	33	33,9	58,3	33,9	30,8	64,5	30,8
14:50	35,5	41,6	28,75	34,2	47,7	34,2	32,2	61,6	32,2	33,9	61,1	33,9	29,6	68	29,6
15:00	35,5	42,2	28,82	34	48,8	34	31,8	64,3	31,8	33,2	62,5	33,2	28,2	73,3	28,2

Source: Prepared by the authors

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