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Thermal Sensation Analysis in the Building of Universitas Ichsan Gorontalo

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Abstract

Gorontalo City is characterized by a tropical climate, where thermal comfort is a crucial component to achieve, particularly for educational activities aimed at students. The thermal comfort is affected by various factors, namely building design, internal, and external factors. The university building represents a facility where face-to-face learning and teaching activities occur. The purpose of the current study is to analyze the perceived thermal comfort of students during classroom activities with three different air conditioning (AC) settings (16, 22, and 27 ºC) in theUniversitas Ichsan Gorontalo campus building. This research employed a quantitative descriptive method, comprising thermal measurements inside the classroom and questionnaire distribution to students to collect thermal sensation data. The research object was conducted in three separate classrooms during the time range of 08.00-15.00 Central Indonesia time. The results revealed that most students felt neutral and comfortable in the three different AC settings inside the classroom. Nevertheless, it should be noted that thermal comfort could be influenced by other factors, such as physical activity and clothing. Consequently, further research could be conducted by taking into consideration these factors and engaging the participation of teachers and staff to acquire a more comprehensive understanding of thermal comfort in the campus building.

Keywords: Thermal comfort; thermal sensation; clasroom

1. Introduction

Indonesia is a country characterized by its archipelagic nature and tropical climate. The country's territory encompasses a diverse range of environments, including highlands, lowlands, and mountains, which give rise to varying air temperatures, forming a vertical climate from lowlands to mountains. This vertical climate is characterized by hot, cool, and cold climates. This variability is due to Indonesia's astronomical location, which lies between 6 ºC N-11 ºC S and 95 º E-141 º E, placing it in a low latitude zone and thus resulting in a tropical climate. Among the physical environmental factors affecting the level of comfort while working is thermal comfort. Thermal comfort is a subjective feeling that describes a person's level of comfort with the temperature of their environment. In the context of sensation, thermal comfort is often described as a condition in which a person does not feel too hot or too cold in a given environment [1].

Thermal comfort is essential for the human body to function optimally in various settings, including homes, schools, and workplaces. Comfort is influenced by microclimate variables, such as solar radiation, air temperature, humidity, and wind speed. Additionally, several individual/subjective factors, such as clothing, acclimatization, age, food/drink intake, obesity, health status, gender, and skin color, can affect comfort levels [2].

According to Humphreys and Nicol, an individual's adaptation to their surrounding temperature also affects their thermal comfort [3]. Individuals who are accustomed to living in hot or tropical climates will have a higher level of comfort than those who are used to living in cooler climates, such as Europe.

Thermal discomfort can be caused by excessively high air temperature, which is influenced by high solar radiation. Vegetation not only contributes to creating comfortable indoor spaces, but can also save energy [4]. Vegetation plays an important role in urban climate and microclimate inside buildings [5].

The environment plays a crucial role in influencing human thermal comfort and productivity within and around buildings. Environmental conditions, such as excessively hot or cold air temperatures, can impact room comfort and work performance [6].

Sunlight reflection, airflow, and vegetation surrounding buildings are some environmental factors that can affect thermal conditions inside and around buildings. Numerous studies have demonstrated that adequate vegetation and airflow can lower air temperatures around buildings and enhance room comfort.

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Additionally, the thermal environment is also influenced by the use of materials and building architecture. Factors such as building orientation, ventilation openings and windows, as well as the use of materials on the front facade of the building, can affect the thermal conditions inside and around the building.

Based on these influences, preliminary observations were conducted on the thermal environment conditions outside and inside the buildings of Universitas Ichsan Gorontalo. The initial observations revealed that the external campus area is highly arid, primarily due to the lack of vegetation within the campus surroundings, resulting in elevated air temperatures. Furthermore, a significant portion of the exterior of the buildings has been paved with concrete, and there is a lack of vegetation in the form of green spaces. Consequently, sunlight radiation is reflected back into the air, causing higher air temperatures due to the reduced absorption capacity of the ground surface.

The thermal condition in the building of Ichsan Gorontalo University is still considered uncomfortable. From the architectural aspect, the openings in the form of ventilation and windows in each room use permanent glass material, so they cannot be opened. This is because each room uses air conditioning (AC). If the electricity goes out or the AC is damaged, the room temperature becomes hot. In certain conditions, users of the space become uncomfortable due to the lack of air circulation. The openings in the campus building are also not up to standard. The corridor with minimal openings results in a lack of lighting and airflow entering the building. This certainly also disturbs the comfort of the building users [7].

1.1. Thermal comfort

Thermal comfort is a thermal condition perceived by humans that is influenced by the environment and objects surrounding its architecture [8]. This view shows that thermal comfort is influenced by several factors, one of which is the architectural environment. If the architecture is not in accordance with planning standards, it can affect the thermal comfort of a room [9] explains that the definition of thermal comfort is the thermal balance achieved by the exchange of heat between the human body and the thermal environment at an appropriate level.

Six factors affect thermal comfort according [10]:

- Air temperature
  Air temperature is one of the most dominant factors in determining thermal comfort. Units used for air temperature include Celsius, Fahrenheit, Reamur, and Kelvin. Dry bulb temperature, which is the temperature indicated by a regular thermometer bulb in a dry condition, is often used to determine air temperature. Humans are said to be comfortable when their body temperature is around 37° Celsius. Human body temperature is highly influenced by the temperature of their surroundings, and in this case, the laws of thermodynamics apply, stating that temperature will transfer from a place with a lower temperature.
- Radiant Temperature
  Radiant temperature is the heat that radiates from objects that emit heat. Radiant temperature is greater than air temperature in terms of how we release or receive heat from the environment. Each direction of a building has a different amount of radiation formed by the direction of the building that borders the outside and the sunlight that enters. Therefore, when constructing a building, the value of radiant temperature should be taken into account.
- Wind speed
  Wind speed is an important factor in thermal comfort. Wind speed is the speed of horizontal airflow at a height above the ground. Wind speed is influenced by the characteristics of the surface it passes over. Still air in a closed space can cause occupants to feel stiff or sweaty. The more uncomfortable the conditions, the higher the required wind speed.
- Relative humidity
  Relative humidity is the ratio of the amount of water in the air to the maximum amount of water vapor that the air can hold at that temperature. Humidity in a place will affect the transfer of heat to and from the body. An environment with high relative humidity inhibits the evaporation of sweat from the skin. In a hot environment, less sweat evaporates due to high humidity, causing discomfort for individuals in that environment.
- Clothing insulation
  Thermal comfort is greatly influenced by the insulation effect of the clothing we wear. Clothing reduces the release of body heat. Therefore, clothing is classified based on its insulation value. The unit commonly used for measuring clothing insulation is Clo. The comfortable limit for clothing is $n \leq 0.5$ Clo. The total Clo value can be calculated by adding the Clo value for each type of clothing.
- Metabolism level
  The level of metabolism is the heat generated within the body during activity. The more physical activity is done, the more heat is produced. The more heat the body produces, the more heat needs to be removed to prevent overheating. Metabolism is measured in MET (1 MET = 58W/m^2 of body surface area). An average adult human has a skin surface of 1.7 m^2, and a person in thermal comfort with a 1 MET activity level will have a heat loss of approximately 100 W. When assessing the level of metabolism, it is important to use the average human activity level shown in the last hour.

1.2. Thermal comfort limit

The thermal comfort limit varies depending on the geographic location and the human subjects being studied [11] can be see seen Table 1.

Table 1. Thermal comfort limits

Author	Country	Human Groups	Comfort limit
ASHRAE	USA (30ºN)	Scientist	20.5ºC –24.5ºCTE
Rao	Calcutta (22ºN)	India	20.5ºC – 24.5ºCTE
Webb	Singapura Equator	Malaysia China	25ºC–27ºC TE
Mom	Jakarta (6ºN)	Indonesia	20ºC–26ºC TE
Ellis	Singapore Equator	Europe	22ºC–27ºC TE

1.3. Thermal comfort zone in a building

1. According to Webb the thermal comfort zone for Indonesians [12]:
   a. Cool 20.5°C (TE) to 22.8°C (TE)
   b. Thermal comfort-optimal 22.8°C (TE)
   c. Optimal comfort 26.2°C (TE)
   d. Warm 26°C – 27.1°C (TE)
2. According to Mom and Wiesebrimn the thermal comfort zone for Indonesians is divided into three zones as follows [12]:
   a. Cool comfortable 20.5°C - 22.8°C (TE)
   b. Comfortable-optimal 22.8°C-25.8°C (TE)
   c. Warm-comfortable 25.8°C-27.1°C (TE)
3. The Indonesian thermal comfort standard SNI T-14-1993-03 has three categories:
   a. Cool comfortable, 20.5°C-22.8°C, relative humidity 50%-80%
   b. Optimal comfort, 22.8°C-25.8°C, relative humidity 70%-80%
   c. Almost comfortable, 25.8°C-27.1°C, relative humidity 60%-70%

Furthermore, thermal environmental condition are also influenced by the use of materials and building architecture. The orientation of building, ventilation openings and windows and the use of materials on the building's façade can also influence thermal conditions within and around building [13].

Based on these influences, an initial observation was conducted on the thermal environmental conditions outside and inside the Ichsan Gorontalo Unoversity campus building. The initial observation result indicated that the exterior of the campus was very arid, primarily due to a lack of vegetation in the campus environment resulting a hot air temperature around the campus. Additionaly, most the exterior building surfaces have been paved with concrete and there is al lack of vegetation such as grass. This inevitably leads to the reflection of sunlight back into air, causing higher air temperatures due to the absence of heat absorption from the ground surface.

In terms of architecture the ventilation openings and windows in each room consist of permanent glass materials that cannot be opened. This is due to the use of air conditioning (AC) in every room. In the event a power outage or AC malfunction, the indoor air air temperature becomes hot. The orientation of the Ichsan Gorontalo University building faces west, where the air temperature in the campus environment is extremely hot from 12:00 PM to 4:00 PM local time (Wita). The front façade of the building is predominantly made of glass material from the first to the third floor without any openings. Most of the wall materials are made of bricks, the ceiling material is plywood and the roof materials is zinc.

The city of Gorontalo has a tropical rain forest climate with temperatures between 22-33ºC. The relative humidity in the city of Gorontalo is a ± 82% rainy days per year [14].

The purpose of this research is to analyze the thermal sensation in the University campus buildings Ichsan Gorontalo. This research was carried out in order to contribute to science in the field of architecture and development of more sustainable buildings and to create more comfortable thermal environment conditions in and around buildings.

2. Research Method

The research method employed in this study is quantitative descriptive method, which involves collecting data through literature review, field observations, temperature and humidity measurements, as well as questionnaires.

The population of this study is students taking classes in the buildings of UniversitasIchsan Gorontalo. The sample is taken through purposive sampling with the criteria of students who are in classroom C.14 (1st floor), classroom A1 (1st floor), and Architecture Studio (3rd floor) between 8.00 am to 3.00 pm Central Indonesia Time.

The research location is at Ichsan Gorontalo University campus, located Drs. Achmad Nadjamuddin No. 10 street, Dulalowo Selatan Subdistrict, Kota Tengah Dostrict, Gorontalo City, can be seen in Fig. 1. Data collection was conducted in the middle of the classroom using a data collection technique consisting of observation, thermal measurement related to temperature and air humidity, and collection of thermal sensation data with questionnaires filled out by students while inside the classroom. The collected data will be analyzed using descriptive statistical techniques. Furthermore, the data from the measurements and questionnaires will be analyzed to find the relationship between air temperature and thermal sensation perceived by the students.

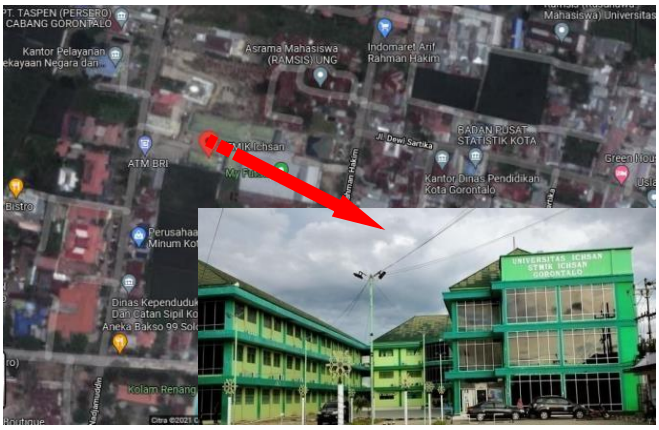

Figure 1. Ichsan University of Gorontalo

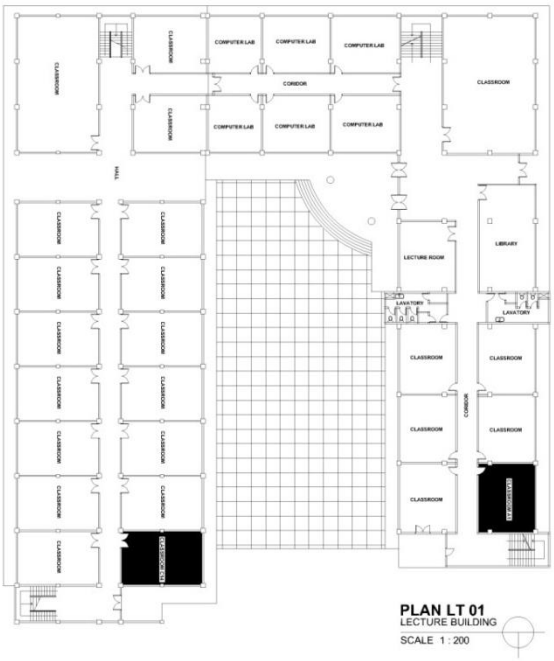

Figure 2. Floor plan 1 Universitas Ichsan Gorontalo

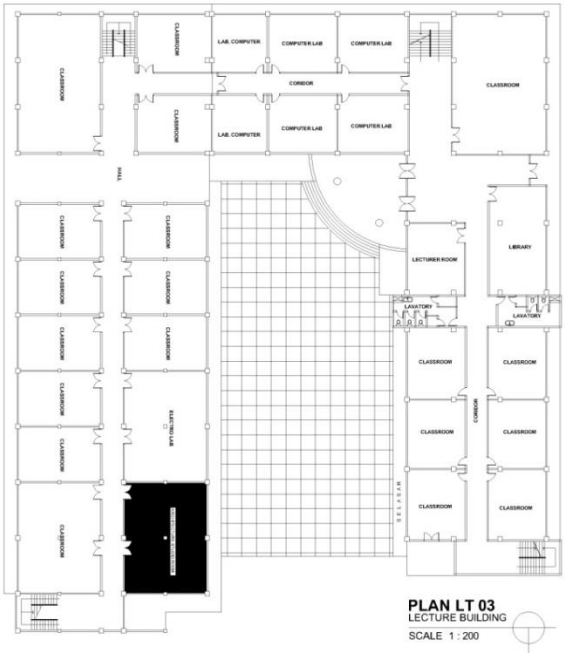

Figure 3. Floor plan 3 Universitas Ichsan Gorontalo

The research samples were taken from two classrooms, namely C.14 and A1, located on the first floor of the building. The building is oriented towards the West, and both rooms have different characteristics, can be seen Fig. 2.

The research object on the third floor was only the Architecture studio room, as the adjacent building on the right was a faculty room that was not included in the study, can be seen Fig. 3.

The Fig. 4 is an example representing other rooms for placing measurement points where measurement tools will be placed in each room.

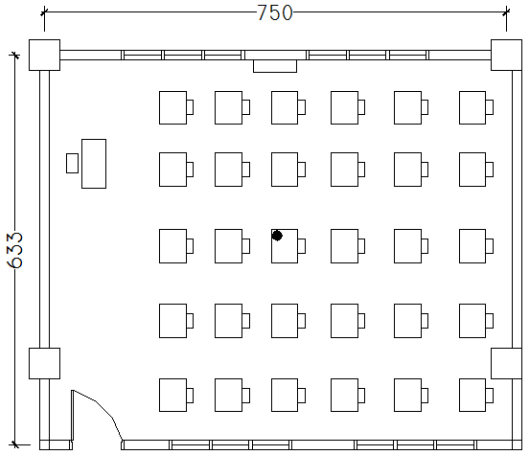

Figure 4. Measurement point in classroom

The selected research objects are classrooms C.14 and A1, and the Architecture Studio room located on the first and third floors. The selection of these research objects is based on their different and interesting characteristics to be investigated regarding thermal comfort.

Classrooms C.14 and A1 have different characteristics and are relatively small compared to the Architecture Studio room. These rooms have different building materials. Classroom C.14 and the Architecture Studio room have one wall made of glass material, while classroom A1 has all walls made of brick material.

3. Result and Discussion

3.1 Thermal environmental condition

The climate of Gorontalo city, based on climate indicators data from the Central Bureau of Statistics throughout 2021, has an average air temperature of 27.10°C with a minimum average temperature of 21.60°C and a maximum average temperature of 35.10°C. The average humidity is 85%, with a minimum average humidity of 43% and a maximum average humidity of 100% [14].

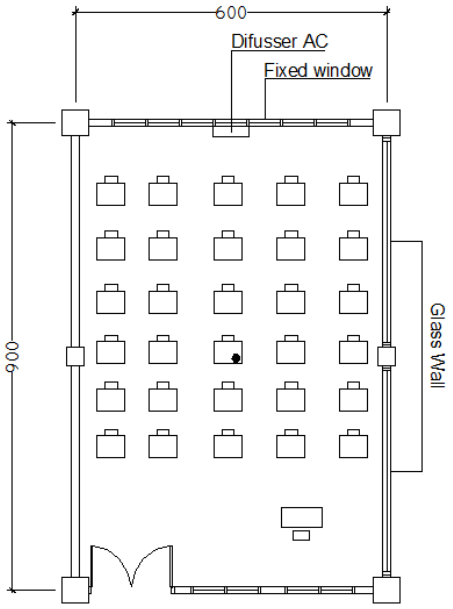

Figure 5. Floor plan of classroom C14, 1st floor

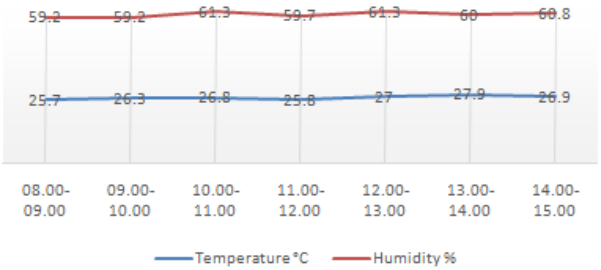

Figure 6. Temperature and humidity in Classroom C.14, 1st floor

1. Classroom C.14, 1st floor

Classroom C.14 is located on the first floor, with an area of 54 m^2, a length of 9 m^2 and a width of 6 m^2. The room has a rectangular shape and is oriented towards the west. One side of the room's wall is made of glass, while the other side is made of brick material and there are two fixed windows, can be seen Fig. 5.

a. Thermostat 16 °C.

The air temperature inside classroom C.14 varied between 25.7°C to 27.9°C, with an average humidity of 60.3%. The lowest temperature occurred at 11:00-12:00 Central Indonesia time with a value of 25.8°C, while the highest temperature occurred at 13:00-14:00 Central Indonesia time with a value of 27.9°C. The highest humidity occurred at 10:00-11:00 and 12:00-13:00 Wita with a value of 61.3%, while the lowest humidity occurred at 08:00-09:00 Wita with a value of 59.2%.

Based on the thermal conditions in the room, the sensation experienced by the respondents (students) can be seen in Fig. 6. Based on the chart, the majority of respondents can be seen Fig. 7 felt comfortable in the room. More than 66.7% of respondents felt comfortable, while only 22.2% of respondents felt slightly comfortable.

In terms of thermal sensation, the majority of respondents felt neutral, which was 59.3% of the total respondents. A total of 33% of respondents felt cold and only 7.4% of respondents felt hot. This indicates that the thermal conditions in the room tend to be optimal and in line with the preferences of the majority of respondents.

Furthermore, only 11.1% of respondents felt very comfortable. However, overall, this data shows that the level of thermal comfort in the room is already quite good and satisfactory for the majority of respondents.

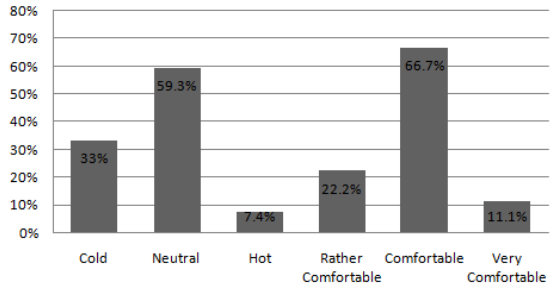

Figure 7. Respondents' thermal sensation charts, Classroom C.14

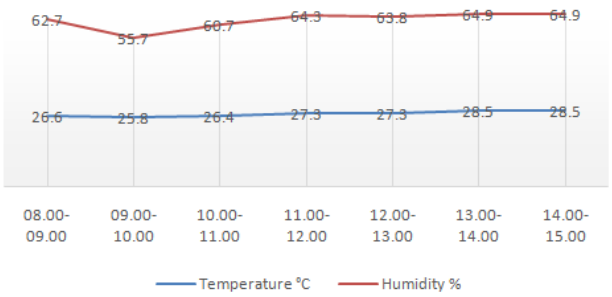

Figure 8. Temperature and humidity in Classroom C.14, 1st floor

b. Thermostat 22°C

The temperature inside classroom C.14 exhibited a significant fluctuation during the observed period, ranging from 25.8°C to its peak of 28.5°C during the 13:00-14:00 Central Indonesia Time interval. The temperature then stabilized at 28.5°C during the 14:00-15:00 interval. Meanwhile, the relative humidity of the room ranged from 55.7% to 64.9%, with less significant fluctuations compared to temperature.

The perceived thermal sensation of the respondents (students) based on the thermal conditions inside the room can be seen in Fig. 8. The chart indicates that most respondents are comfortable in the room, with 41.7% feeling comfortable and 33.3% feeling slightly comfortable. However, 25% of respondents feel very comfortable, indicating the potential to improve the level of thermal comfort in the room can be seen Fig. 9.

Regarding the thermal sensation, half of the respondents (50%) felt cold, while 37.5% felt neither hot nor cold. This implies that the thermal conditions in the room are generally too cold for the majority of the participants.

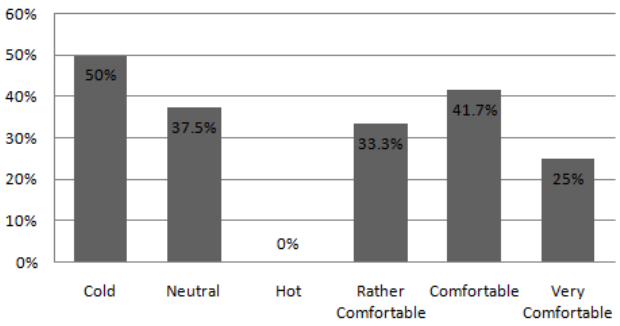

Figure 9. Thermal sensation chart of respondents in classroom C.14

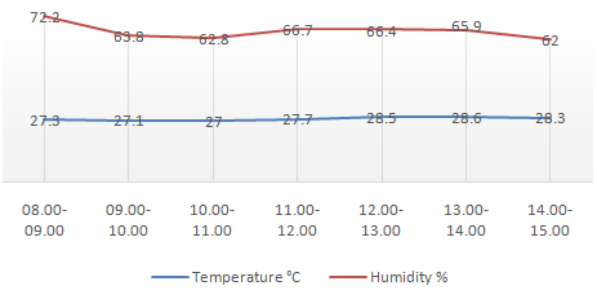

Figure 10. Temperature and humidity inside classroom C.14, 1st floor

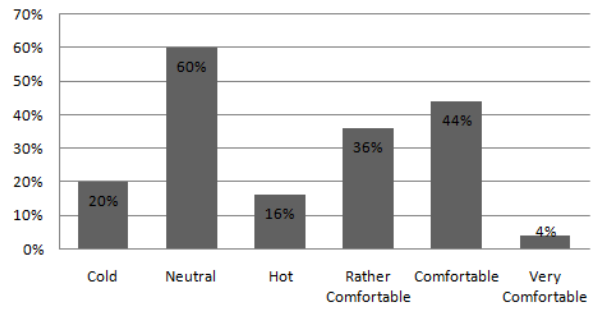

Figure 11. The thermal sensation felt by respondents in classroom C.14

c. Thermostat 27°C

Throughout the observation period, the thermal conditions in the room remained steady, with temperatures hovering between 27-28.6°C. The relative humidity, on the other hand, fluctuated between 62-72.2%. At its peak, the temperature hit 28.6°C between 1:00-2:00 PM, while the humidity peaked at 72.2% between 8:00-9:00 AM (Central Indonesian Time zone).

Figure 10 shows the sensations felt by respondents who were in the room with the thermal conditions as previously described. The chart indicates that most students (60%) have a neutral perception of the thermal conditions in the room, while 44% find it comfortable and only 4% feel very comfortable. However, 20% of students feel cold and 16% feel hot. Additionally, 36% of students find the thermal conditions slightly comfortable.

A significant percentage of students feeling cold and hot, indicates the presence of differences in thermal preferences and needs among individuals in the room can be seen Fig. 11.

2. Classroom A1, first floor

Classroom A1 is located on the first floor, and it has an area of 47.475 m2, with a length of 750 m and a width of 633 m. Constructed with brick walls, the classroom can be seen Fig. 12 has no natural openings for ventilation and instead relies on a split air conditioning system for air circulation.

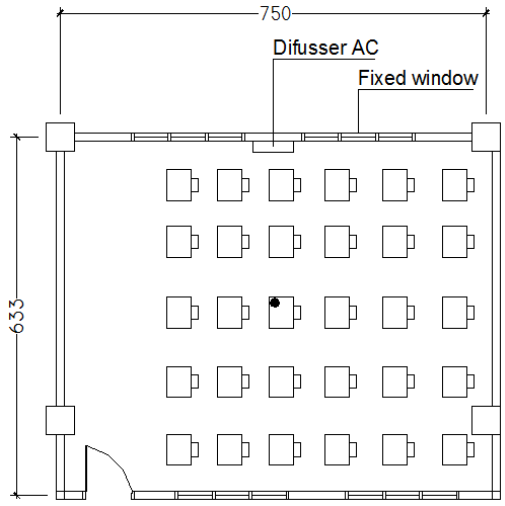

Figure 12. Classroom A, 1st floor

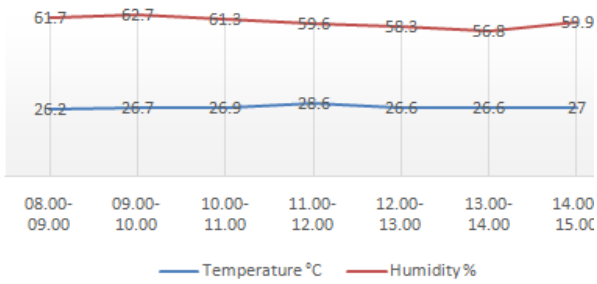

Figure 13. Temperature and humidity in classroom A1, 1st floor

a. Thermostat 16°C

According to the graph, there were significant fluctuations in temperature and humidity within classroom A1 during the observation period. The highest temperature was recorded between 11:00-12:00 WITA, reaching 28.6°C with a humidity level of 59.6%, while the lowest temperature was recorded from 08:00-09:00 WITA, with a temperature of 26.2°C and a humidity of 61.7%. Despite the fact that the relative humidity remained within the comfort range, the considerable temperature fluctuations could affect the thermal comfort in the room.

Based on the previous thermal conditions, the following figure shows the perception of thermal sensation experienced by respondents (students) can be seen Fig. 13.

The graph above indicates that the majority of respondents (80%) experience a cold sensation in the room, with only 20% feeling neutral and none feeling hot. While 60% of respondents feel comfortable, the remaining 40% feel very comfortable. The majority of respondents feeling cold may be due to significant temperature fluctuations during the observation period.

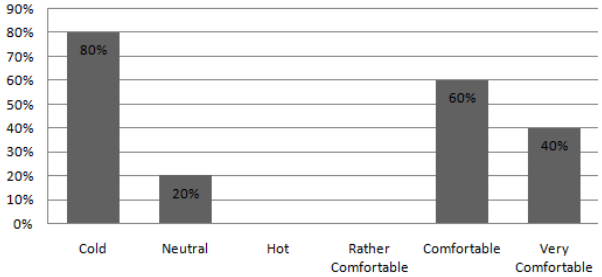

Figure 14. Thermal sensation graph of respondents, classroom A1

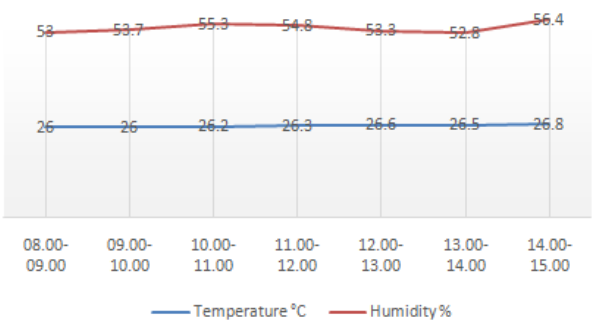

Figure 15. Temperature and humidity inside classroom A1, 1st floor

Nevertheless, the majority of respondents still feel comfortable or very comfortable, implying that the thermal conditions within the room are still quite sufficient to meet human comfort can be seen Fig. 14.

b. Thermostat 22°C

The graph above shows that the room temperature remained fairly constant within a range of 26-26.8°C throughout the observation period. Similarly, the relative humidity also had a relatively narrow range of 52.8-55.3%. However, this range still falls within the range of human comfort. Consequently, it can be inferred that the thermal conditions inside this room can be categorized as comfortable. Based on the previously described thermal conditions, the perception of thermal sensation felt by the respondents (students) can be seen in Fig. 15.

The data collected on thermal sensation revealed that the majority of respondents (66.7%) felt neutral towards the existing thermal conditions. Around one-third of the respondents (33.3%) reported feeling cold, while none of them felt hot. Additionally, an equal number of respondents (50%) felt comfortable and very comfortable, respectively. Notably, none of the respondents reported feeling slightly comfortable. This data suggests that the thermal conditions in the room were generally comfortable for most respondents, despite some feeling cold can be seen Fig. 16.

c. Thermostat 27°C

According to the temperature and humidity data provided, the temperature decreased gradually over the observation period. The highest temperature was recorded between 08:00-09:00 WITA at 27.8°C, while the lowest temperature was recorded between 13:00-14:00 WITA at 26°C. The relative humidity remained within the comfortable range, ranging from 47.5-64.4%.

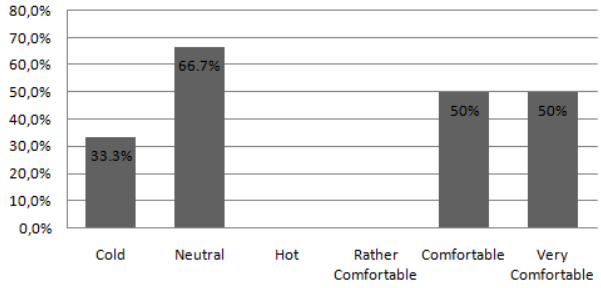

Figure 16. Tthermal sensation of respondents chart, A1 classroom

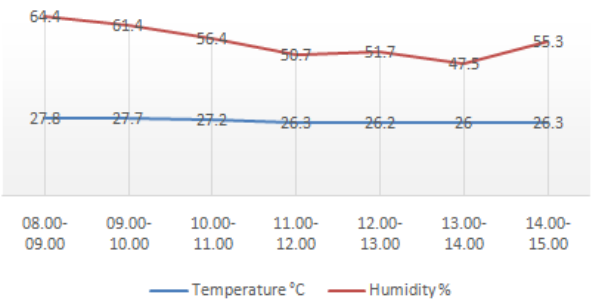

Figure 17. Temperature and humidity inside A1 classroom, 1st floor

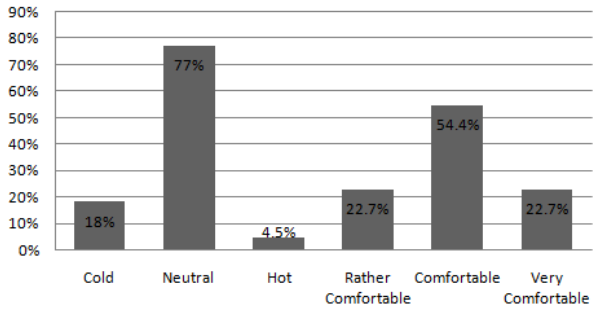

Figure 18.Tthermal sensation of respondents chart, A1 classroom

Based on the thermal conditions as explained, the thermal sensation perceptions felt by respondents can be seen in Fig. 17.

The chart shows that most respondents (77%) felt a neutral thermal sensation. A small percentage of respondents (18%) felt cold, and an even smaller percentage (4.5%) felt hot. In terms of thermal comfort, the majority of respondents (54.4%) felt comfortable with the existing thermal conditions, while a portion (22.7%) felt slightly or very comfortable. Therefore, it can be concluded that most respondents felt fairly comfortable with the thermal conditions, although some experienced sensations of cold or heat can be seen in Fig. 18.

3. Architecture Studio Room, 3rd Floor

The architecture studio is located on the third floor, and it has an area of 108 m^2 with a length of 1200 m^2 and a width of 900 m^2. One side of the room's wall uses glass material, while the other side uses brick material can be seen Fig. 19.

a. Thermostat 16°C

The temperature in the architecture studio gradually decreased over the observation period, as indicated by the temperature and humidity data.

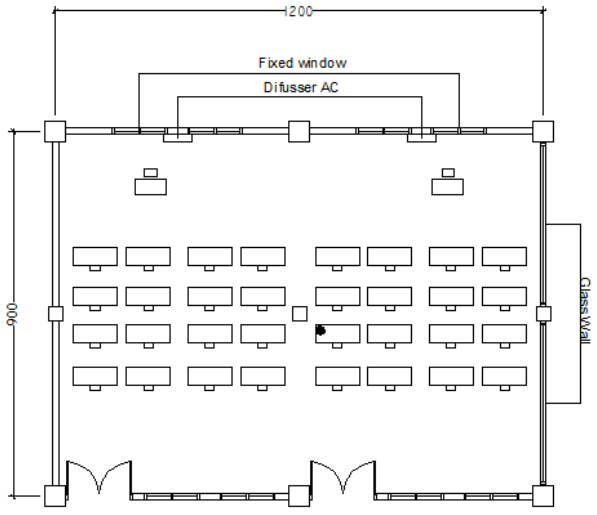

Figure 19. Architecture studio room of 3rd floor,Universitas Ichsan Gorontalo

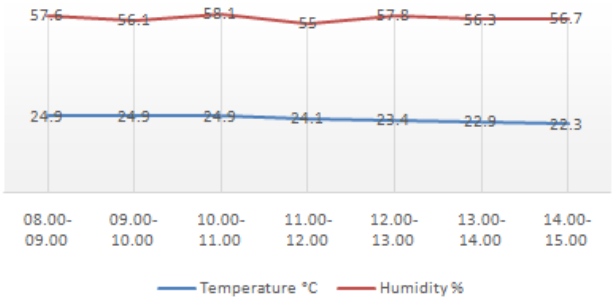

Figure 20. Temperature and humidity in architecture studio room, 3rd floor

The temperature remained stable at 24.9°C, while the humidity ranged from 55-58.1%. Nonetheless, at 11:00-12:00 WITA, there was a considerable drop in temperature to 24.1°C, which then continued to decline until it reached 22.3°C at 14:00-15:00 WITA. While the humidity remained within the comfortable range for humans, fluctuations in temperature can impact the room's thermal comfort.

The Fig. 20 shows the thermal sensation perception felt by respondents (students) based on the thermal conditions inside the room that have been previously described.

The data presented in Fig. 21 shows that most respondents (57.1%) felt comfortable in terms of thermal sensation, followed by feeling neutral (57.1%) and very comfortable (42.9%). On the other hand, feeling cold was reported by 33.3% of the respondents, while only 4.8% felt hot. Unfortunately, there is no data available for the "slightly comfortable" category.

It can be concluded that the majority of respondents felt a comfortable and neutral thermal condition, while the sensation of feeling cold and hot was only felt by a small number of respondents.

b. Thermostat 22°C

The temperature and humidity data that was recorded show that the room temperature fluctuated during the observation period, suggesting that it can change depending on the time and environmental conditions. At specific hours, notably from 11:00-12:00 WITA, the temperature significantly increased and reached 26.3°C with a humidity level of 63.2%.

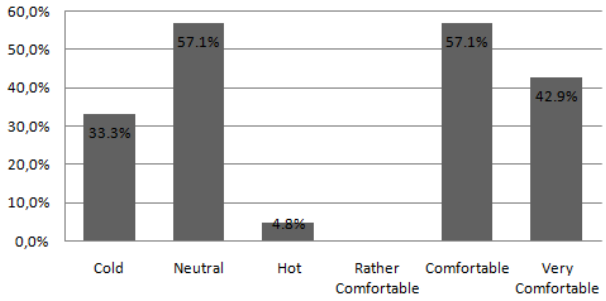

Figure 21. Thermal sensation chart of respondents in architecture studio room

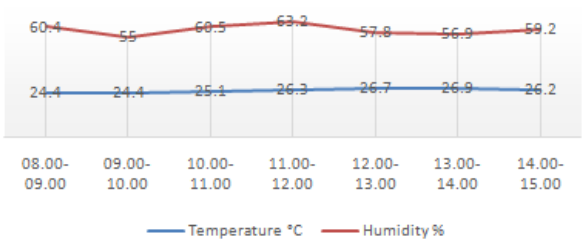

Figure 22. Temperature and humidity in architecture studio room, 3rd floor

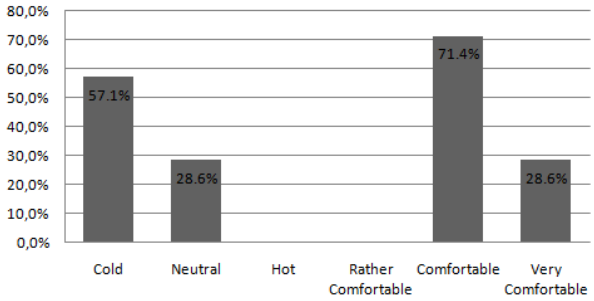

Figure 23. Thermal sensation chart of respondents in Architecture Studio room, 3rd floor

The thermal sensation perceived by respondents (students) in the room depends on the thermal conditions inside the room, as show in the Fig. 22.

The majority of respondents (students) perceived a thermal sensation in the room, with 57.1% feeling cold, 28.6% feeling neutral, 71.4% feeling comfortable, and 28.6% feeling very comfortable. None of the respondents felt hot or slightly comfortable. These results indicate that most respondents felt comfortable with the room's thermal condition. However, some respondents experienced cold and neutral sensations, which could mean that the room temperature is too low for certain individuals can be seen Fig. 23.

c. Thermostat 27°C

The temperature and humidity data presented indicate that there were minor fluctuations observed throughout the study period. At 8:00-9:00 AM WITA, the temperature rose to 26°C, with a humidity of 60.7%. By 9:00-10:00 AM WITA, the temperature dropped to 25.8°C, with a humidity of 54.7%. Between 10:00-11:00 AM WITA, the temperature rose again to 26.5°C, with a relative humidity of 58.3%.

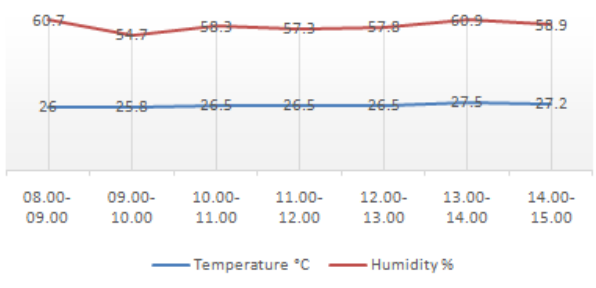

Figure 24. Temperature and humidity inside the architecture studio room, 3rd floor

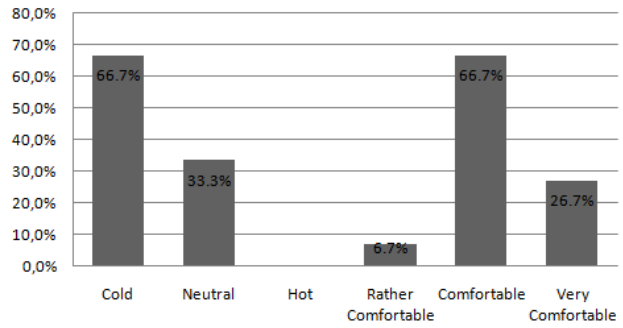

Figure 25. Thermal sensation chart of respondents in Architecture studio room

From 11:00 AM-3:00 PM WITA, the temperature remained steady, hovering around 26.5-27.5°C, while the humidity was recorded between 57.3-60.9%.

Based on the thermal condition notes, it can be concluded that the thermal sensation experienced by respondents can be described through the chart presented can be seen Fig. 24.

Based on the thermal sensation data above, the majority of respondents, 66.7%, felt cold sensation, 33.3% felt neutral sensation, and none of the respondents felt hot sensation. In terms of thermal comfort level, 6.7% of respondents felt slightly comfortable, 66.7% of respondents felt comfortable, and 26.7% of respondents felt very comfortable.

From the analysis, it can be concluded that most respondents felt comfortable with the thermal conditions in the observed Arcitecture Studio room can be seen Fig. 25.

The results of this study describe the thermal conditions in three lecture halls. The majority of respondents felt comfortable anda neutral in terms of thermal comfort, although a small portion of respondets felt slightly comfortable, cold, or hot. Significant tetmperature fluctuations and lower humifity variations can be considered for improving the thermal regulation in the room.

The results of this study illustrate the thermal environment in lecture rooms. Most participants indicated that they experienced a comfortable and neutral thermal sensation, while a minority reported slight comfort, coldness, or warmth. It is important to take into account significant temperature fluctuations and lower humidity variations when aiming to enhance thermal regulation in these rooms.

In thermal and indoor comfort research, several factors need to be considered, including air temperature, humidity, air circulation, wind velocity, radiant temperature, physical activity, and individual preferences. Numerous studies have been conducted to understand thermal preferences in order to seek optimal solutions for creating comfortable thermal conditions indoors.

The ISO standard [15] serves as a frequently utilized resource in this context, outlining principles and parameters for assessing human thermal comfort. It offers guidance on temperature ranges, humidity levels, and other relevant factors that can be utilized as references when designing indoor thermal regulation systems.

The difference between previous research and the present study pertains to the specific emphasis on particular lecture rooms, specifically C.14, A1, and architecture studios. The investigation involved monitoring temperature and humidity fluctuations within a designated timeframe, while also evaluating the respondents' (students) perceived sensations and comfort levels.

Variations in variables and research methods used for studying indoor thermal comfort can result in discrepancies between previous studies and the data presented. These discrepancies arise from differences in research context, methodologies employed, and the specific population being examined.

4. Conclusion

The analysis of temperature and humidity in three sample classrooms showed that most of the respondents felt comfortable with the thermal conditions and perceived a neutral sensation. Nonetheless, some respondents experienced either cold or hot sensations. This suggests that the variations in individual thermal preferences and needs can impact the overall thermal sensation in the room. It is, therefore, crucial to take into account a range of temperature and humidity levels that can cater to the different needs of room users to ensure optimal thermal comfort, 66.7% of respondents felt comfortable at a thermostat setting of 16 degrees Celcius, 66.7% felt comfortable at a thermostat setting of 22 degrees Celcius and 66.7% felt comfortable at a thermostat setting of 27 degrees Celcius with different rooms.

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