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To cite this article: R Mulyadi *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **875** 012004

IOP Conf. Series: Materials Science and Engineering **875** (2020) 012004 doi:10.1088/1757-899X/875/1/012004

Adaptive Thermal Comfort of Elementary School Student (A Case study of the West Coastal Area of South Sulawesi)

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Abstract. This research aims to study the adaptive thermal comfort in elementary school buildings in the west coastal area of South Sulawesi. It was conducted by field survey method to obtain personal data (clothing and metabolic rate) and environmental parameters such as air temperature and humidity, mean radiant temperature (MRT) and the airflow. During the measurements of environmental parameters, the students filled out questionnaires to find out their perceived comfort level by the Thermal Sensation Vote (TSV) and Thermal Comfort Vote (TCV). In addition, respondents are also asked to give an opinion on their desired thermal preference. The results of the environmental parameters measurements were used as references to calculate the Predicted Mean Vote (PMV), Operative Temperature (T_{op}) and Predicted Percentage of Dissatisfied (PPD). The results show that the condition of the elementary school classrooms along the west coast of South Sulawesi are generally in high temperatures. However, most respondents still feel comfortable and able to adapt to these conditions.

1. Introduction

It is currently developing two approaches related to thermal comfort. The first approach is called the static approach which refers to the results of the study of the thermal perception of respondents. It is based on the results of research PO Fanger in the 1970s [1] and later on adopted by ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) as a standard of prediction of thermal comfort (ASHRAE Standard 55) [2] and ISO 7730 [3] in the form of an index of thermal comfort PMV-PPD.

The second approach is called adaptive approaches. This approach using respondents from building users, which has been adapted to the climatic conditions. Basically, the study of adaptive thermal comfort is an attempt to determine the thermal neutrality, acceptability of thermal conditions (thermal acceptability), and the preference of thermal conditions (thermal preference) of respondents. The prediction of adaptive thermal comfort models assumes that the occupant or user of the building (respondents) rather than as a passive recipient of the thermal environment, such as in the case of experimental subjects climate chamber, but on the contrary, have an important role in creating conditions comfort condition by three types of adaptation, namely: behavioral setting, physiological, and psychological [4].

Thermal comfort standards such as ASHRAE Standard 55 [2] and ISO 7730 [3] has been widely used as a standard thermal comfort in various countries. However, this standard is more widely used for a room with artificial conditioning (AC/Air-Conditioning). For buildings with natural conditioning, which is no less relevant standards for use [17]. ASHRAE Standard 55 using a seven-point scale to measure the thermal sensation perceived (Thermal Sensation Vote/TSV). The seven-point scale according to ASHRAE are rated +3 (hot), +2 (warm), +1 (slightly warm), 0 (neutral), -1 (slightly cool), -2 (cool), and -3 (cold). It also conducted a survey of TSV (Thermal Sensation Vote) using Bedford scale of thermal comfort. Bedford scales better known by the name of the response of comfort (comfort response) [13]. Thermal Comfort Vote (TCV) using a scale of Bedford which also consists of seven-points value is +3 (much too warm), +2 (too warm), +1 (comfortably warm), 0 (comfortable), -1 (comfortably cool), -2 (too cool), and -3 (much too cool).

Indoor thermal comfort will increase work productivity. A long study says that there is an influence of the thermal quality of a classroom with student achievement or student [5]. There is a correlative relationship between the quality of the room includes thermal comfort and student achievement. Research on thermal comfort in classrooms have been carried out in various places in the world as conducted by Buratti and Ricciardi [6], Corgnati, Ansaldi, and Filippi [7], Corgnati, Filippi, and Viazzo [8], Hwang, Lin, and Kuo [9], Kwok and Chun [10], Mors et al [11], Teli, Jentsch, and James [12] included in the tropics, namely in Singapore by Wong and Khoo [13].

Several recent studies also showed a positive relationship between the quality of the room (including the thermal conditions) with student achievement by Mendell and Heath [14], and Sensharma, Woods and Goodwin [15], and Baharuddin et al [16]. Therefore, thermal comfort becomes very important to the study, in order to achieve a conducive learning process and give satisfactory results for students.

School buildings with comfortable thermal conditions can help students achieve optimal learning outcomes. But on the contrary, the achievement of optimal learning outcomes will be difficult to produce in uncomfortable school buildings. This research is intended to analyze the thermal comfort of students in elementary school buildings on the west coastal area of South Sulawesi by using the adaptive approach method as described above.

2. Method

The survey was conducted to obtain data on the condition of elementary students which include: personal data (clothing and metabolic rate) and the measurement of environmental parameters: air temperature, air humidity, mean radiant temperature (MRT) and the airflow. At the same time, students are asked to fill out questionnaires asking the perceived comfort level of occupants using the Thermal Sensation Vote (TSV) and Thermal Comfort Vote (TCV). TSV is measured using ASHRAE scale, while TCV measured using Bedford scale. In addition, respondents are also asked to give an opinion on the desired thermal conditions (thermal preference), if the thermal environment at the time it was acceptable or not. The results of measurements of environmental parameters will be used as a reference to calculate the Predicted Mean Vote (PMV), Operative Temperature (T_{op}) and Predicted Percentage of Dissatisfied (PPD). The result of this calculation will be compared with the comfort perceived by the user of the room (the students).

Measurements were taken at a height of 1 meter above the floor following the measurement techniques of Feriadi and Wong [17]. Measurements were performed for 5 hours, ranging from 08: 00 – 12: 00 and 13: 00 – 14: 00 pm, with intervals of 1 hour for each respondent. It also will be measured against a dry bulb temperature, humidity, air velocity, and MRT.

The respondents were given a questionnaire to assessing the thermal conditions, acceptability of thermal conditions, and preferences of thermal conditions. The collection of questionnaires was conducted in conjunction with the collection of physical measurement data of the environment.

Analysis of the thermal conditions was made by simple linear regression analysis using SPSS software. Values of thermal neutrality are outlined in the form of graphs and tables. Furthermore, analysis acceptability of thermal conditions is done by plotting the average percentage of respondents in the comfortable temperature range. The results were elaborated in the form of graphs and tables. Furthermore, analysis of thermal preferences was done by analyzing the results of the respondent’s responses to the questionnaire.

3. Result and discussion

Data collected from 798 respondents, where 47.4% is boys and 52.6% is girls. The ages varied from 8-13 years old. Table 1 describes the characteristics of respondents.

Table 1. Characteristics of respondents

Variables		Sum (n)	Percentage (%)
Age (Years)	8	13	1.6
	9	190	23.8
	10	256	32.1
	11	243	30.5
	12	82	10.3
	13	14	1.8
Sex	Male	378	47.4
	Female	420	52.6
Clothes	Sport uniforms	68	8.5
	Sports uniforms with hijab	25	3.1
	Boy scout uniforms	293	36.7
	Boy scout uniforms with jacket	1	0.1
	Boy scout uniforms with hijab	95	11.9
	Long-sleeved boy scout uniforms	10	1.3
	National (red-white) uniforms	160	20.1
	National (red-white) uniforms with hijab	109	13.7
	National (red-white) uniforms with vest	30	3.8
	Long-sleeved National (red-white) uniform	1	0.1
	National (red-white) uniforms with jacket and hijab	1	0.1
	National (red-white) uniforms with hijab and vest	5	0.6

Thermal sensation votes based on scale hot (3), warm (2), slightly warm (1), neutral (0), slightly cool (-1), cool (-2), and cold (-3) can be seen at figure 1. The votes indicate that about 35.1% of respondents feel slightly warm, 34.2% feel comfort, and about 17.5% feel slightly cool.

Thermal comfort vote determined by much too warm (3), too warm (2), comfortably warm (1), comfortable (0), comfortably cool (-1), too cool (-2), and much too cool (-3). Most of the respondents (51.1%) feel comfort. About 27.9% feel comfortably warm, and 10.8% of respondents feel comfortably cools as can be seen in figure 2.

Thermal preference measured by the scale of more-hot (1), no change (0), and more-cool (-1). As can be seen in figure 3. Most of the respondents (58.9%) want more-cool. About 39.8% of respondents want no change and feel comfortable with the current condition. Only 1.3% of respondents want more-hot of the current condition.

Thermal acceptance indicates that the current thermal condition can be accepted (1) by respondents or not (0). Figure 4 shows the acceptance of 67.4% of respondents, while 32.6% of respondents have not accepted the condition.

The air velocity vote measured the air velocity condition feels by respondents. It used a scale of no velocity (-2), less velocity (-1), enough velocity (0), fast velocity (1), and very fast velocity (2). Figure 5 shows that 44.5% of respondents feel less air velocity (-1), 42% feel enough air velocity (0) and 11,7% of respondents feel no air velocity.

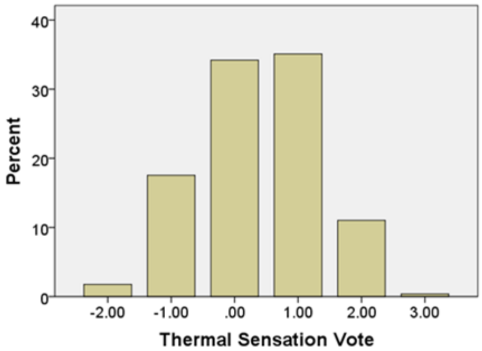

Figure 1. Percentage of thermal sensation vote

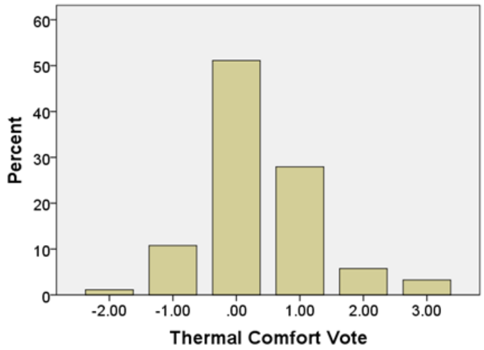

Figure 2. Percentage of thermal comfort vote

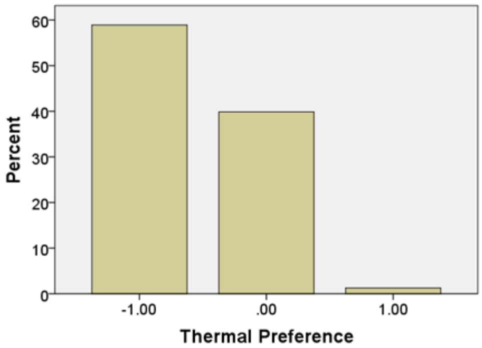

Figure 3. Percentage of thermal preference

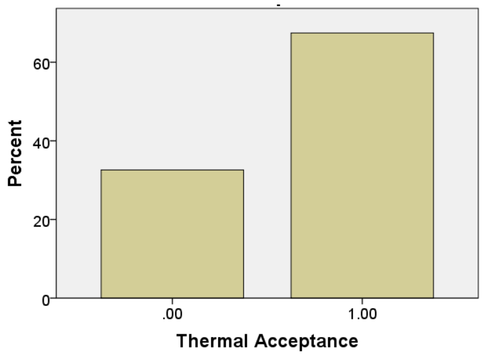

Figure 4. Percentage of thermal acceptance

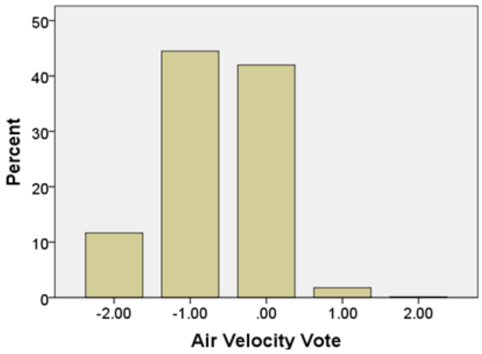

Figure 5. Percentage of air velocity vote

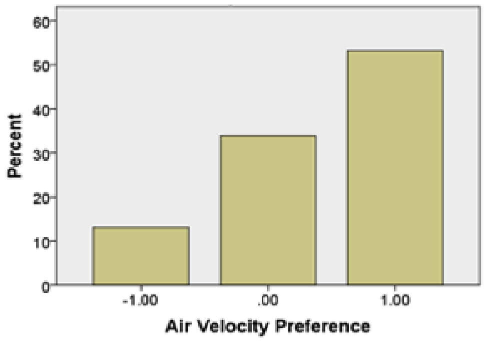

Figure 6. Percentage of Air Velocity Vote

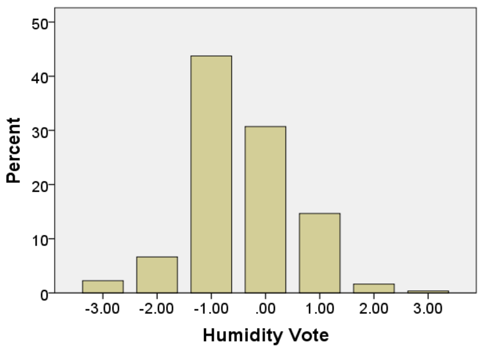

Figure 7. Percentage of Humidity Vote

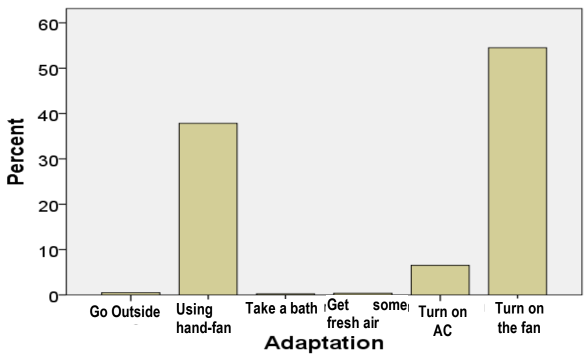

Figure 8. Percentage of thermal adaptation vote

Air velocity preference measured the preference of respondents to the air velocity. Most of the respondents (53.1%) want more air velocity (1), 33.8% respondents feel air velocity is enough (1), and 13% respondents want less air velocity as can be seen in figure 6. There are seven option on questionnaires to assess respondents to the relative air humidity (humidity vote) is extremely too humid (score -3), very humid (value -2), slightly moist (value -1), appropriate (value of 0), slightly dry (value of 0), somewhat dry (value 1), very dry (value of 2), it is too dry (value 3). Figure 7 shows that the majority of 43.7% of respondents felt the room was a bit humid (value -1), there are 30.7% of respondent feel it is appropriate (value of 0), and there are 14.7% of respondents felt a bit dry (value of 1).

There are three options on the questionnaire as an adaptation if the correspondent experiencing high-temperature conditions, namely the fans, turn on the fan, and defeated air-condition (AC). Figure 8 shows that the majority of respondents 54.5% chose turned on the fan if the room air temperature is high, there are 37.8% of respondents felt the fans choose, and there are 6.5% of the respondents chose the air-conditioning. There is another option which is 0.5% opted out of the room, 0.4% would like to get some fresh air, and 0.3% wanted a shower.

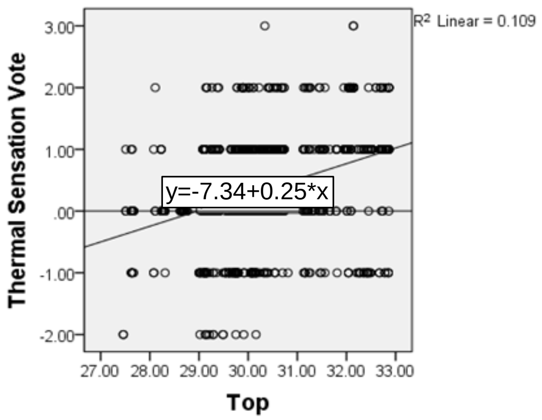

Figure 9. Regression between TSV and T_{op}

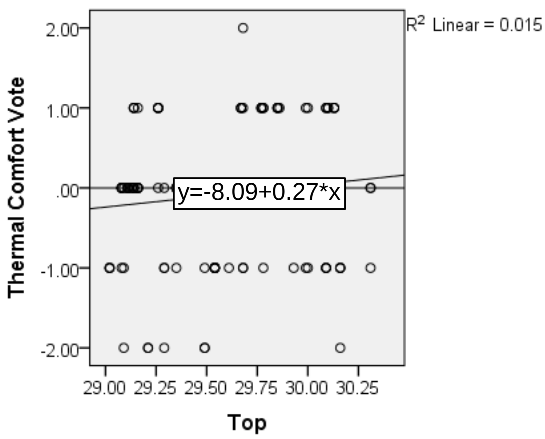

Figure 10. Regression between TCV and T_{op}

Figure 9 shows the relationship between the TSV with operative temperature (T_{op}). The graph shows that the T_{op} ranged between 27.46 – 32.86 °C. The neutral temperature ranges 29.36 °C and considered as high. A high value is caused by the physicality of these children - that are already familiar with the existing thermal conditions so they are able to accept the thermal conditions. Figure 10 shows the relationship between the value of TCV with operative temperature (T_{op}). The graph shows that the T_{op} ranged between 27.46 – 32.86 °C. The comfortable temperature range to 29.25 °C. This temperature is lower than the neutral temperature TSV models.

4. Conclusion

The general condition of classrooms in schools along the west coast of South Sulawesi showed high-temperature conditions mainly before noon has reached 35 °C. Although the measurement results indicate a high temperature, the survey results showed that most respondents still feel comfortable and able to adapt to these conditions. TSV model results in this study show the airflow is higher than the TCP model, it is advisable to conduct additional studies with more data. Therefore, the results of the study, indicating that despite the high temperatures, most respondents still feel comfortable.

Acknowledgment
The authors would like to thank the Laboratory-Based Education (LBE) Research Grant provided by the Faculty of Engineering Universitas Hasanuddin which supporting the financing of this research. Also, many thanks to the students of the Laboratory of Building Science & Technology Department of Architecture for their valuable contribution to this research.

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