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Evaluation of the Effect of Thermal Comfort in PMV-Method Classrooms on Teacher Work Stress Levels in the Dry Tropics (Study at Beru Elementary School, Sikka Regency)

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ABSTRACT: This study aims to evaluate the effect of classroom thermal comfort on the level of teacher work stress in a dry tropical region (Study at SDI Beru, Sikka Regency), using the PMV (Predicted Mean Vote) method. Thermal comfort, which includes temperature, humidity, and air flow, is very important to create a conducive learning environment. Temperature and humidity measurement data were collected using temperature and humidity measuring devices model GSP-6 and RC-4HC for a certain period. In addition to using PMV, this study also used Regression and Correlation data analysis using SPSS. The sample used was a saturated sample. The results obtained in this study indicate that based on the PMV calculation, it was obtained that the temperature and humidity in the classroom varied and often exceeded the ideal comfort range. This condition can increase the level of teacher work stress and reduce productivity, this is in line with the results obtained from the SPSS program obtained validity and reliability testing using SPSS software there are 50 valid and reliable statements, the results of the analysis show that there is a significant linear relationship between work stress and thermal comfort (F Linearity = 30.454; Sig Linearity = .000). Based on these calculations, it can be seen that the regression coefficient value of the thermal comfort variable (X1) is 0.498 with a positive sign at sig 0.000 which is smaller than 0.05, namely 0.000 <0.05. The regression coefficient value of the thermal comfort variable (X1) of 0.498 indicates that there is a positive relationship between thermal comfort and teacher work stress. This means that every one unit increase in thermal comfort will be associated with a 0.498 unit increase in the measured variable (teacher work stress). The significance value (p-value) of 0.000 is smaller than 0.05 (0.000 <0.05). This shows that the results are statistically significant. In other words, there is strong evidence to state that thermal comfort has an effect on teacher work stress. So it can be interpreted that thermal comfort has a positive effect on teacher work stress.

KEYWORDS: thermal comfort, work stress, teacher performance

I. INTRODUCTION

The environment is one of the determinants of a person's performance. The work environment is one of the most important components for a person in carrying out work activities. If the work environment is in good condition or the condition of the workplace is able to motivate workers to be able to work harder, then the environment is able to provide work enthusiasm. A comfortable learning environment is an important factor in supporting an effective learning process. Elfita R, et al (2019).

Sikka Regency is one of the regencies in East Nusa Tenggara whose territory is a dry tropical region. Dry tropical regions generally have unique climate characteristics that affect the environment and human activities. Dry tropical regions are characterized by high temperatures and low rainfall. The average annual temperature usually reaches 20°C to 30°C, with small fluctuations between day and night. Annual rainfall is often less than 500 mm, and most of the rain occurs in a short period of time, usually during the short rainy season Houghton (2009).

Thermal comfort in dry tropical areas can be challenging, especially in the context of buildings and classrooms. Good building design is needed to regulate temperature and humidity to keep it comfortable for its occupants. Snyder & Anthony (1989) Thermal comfort includes temperature, humidity, and airflow. Thermal comfort is not only about air temperature, but also about the comfort of the occupants in it Hildegardis C, (2023) Thermal comfort is an important aspect in a learning environment that can affect the concentration, productivity, and quality of student and teacher learning outcomes. An uncomfortable thermal environment can cause fatigue and obstacles in thinking, thereby reducing academic performance (Yeny & Hidayat, 2019). Thermal

comfort involves three aspects: physical, physiological, and psychological. Physical aspects include temperature, air humidity, and air flow rate. Physiological aspects involve human body temperature and body sweating levels. Psychological aspects involve a state of mind that expresses a person's level of satisfaction with their thermal environment Muhamad Muhaimin et al., (2023).

High temperatures and unstable humidity can cause discomfort for teachers, potentially increasing work stress. Research shows that an uncomfortable environment can interfere with concentration, cause fatigue, and reduce motivation. Renny (2020) The environment can also have an impact on a person's physical condition. Sedarmayanti (2020) states that the environment can be divided into physical, non-physical and psychological environments. Work stress is a condition of tension that creates physical balance, which affects emotions, thought processes and the condition of an employee. Too much stress can threaten a person's ability to deal with the environment. As a result, teachers develop various symptoms of stress that can interfere with their work performance

For teachers, work stress is a common problem and can have a negative impact on the quality of learning. High work stress can lead to decreased motivation, emotional exhaustion, and physical health problems. This will ultimately affect teacher performance in providing effective learning to students. Renny CA., (2020). Work stress can also affect teacher well-being as a whole, including interpersonal relationships and work motivation.

Research related to the influence of thermal comfort on teacher work stress, especially in the context of elementary schools in tropical areas such as Maumere, is still limited. Although several studies have shown the importance of thermal comfort in the learning environment, more specific research is still needed on how thermal comfort affects teacher work stress in elementary schools in tropical areas. This study can help identify the most influential aspects of thermal comfort and provide recommendations for improvements to improve thermal comfort in elementary schools.

The purpose of this study was to analyze the effect of thermal comfort in classrooms in dry tropical areas on the level of work stress of teachers at SDI Beru, and to determine the relationship between thermal comfort and teacher productivity.

II. LITERATURE REVIEW

A. Thermal Comfort

1) PMV Concept

PMV (Predicted Mean Vote)is an index used to predict the average value of votes from a group of people about their thermal feelings. This index uses a seven-point scale from -3 (very cold) to +3 (very hot). A value of 0 indicates a condition of thermal neutrality, which is when the body's heat production is equal to the heat loss to the environment (ISO 7730, 1984).

Thermal comfort according to Szokolay (1973) in the manual of tropical housing and building involves physical, physiological and psychological conditions. Thermal comfort is the result of a person's thoughts expressing their satisfaction with their thermal environment. ASHRAE (American Society of Heating Refrigerating Air Conditioning Engineer) defines thermal comfort as a condition where there is satisfaction with the surrounding thermal conditions. Meanwhile, thermal comfort according to Snyder (1989) is a state of the environment/nature that can affect humans. From this statement, it can be stated that thermal comfort is an empirical formulation which is an experience of feeling where the conditions felt can differ from one person to another. In determining the comfort of a zone/area, it can be stated by looking at the dominant perception felt by a group of samples in the area.According to the opinion put forward by Nugroho (2007), thermal comfort is a state of human mind that indicates the extent to which individuals feel satisfied with thermal conditions. In relation to buildings, comfort can be explained as a state in which users feel comfortable and happy (Karyono, 2001). Thermal comfort is a condition that is influenced by natural factors and can be controlled through architectural design. (Snyder & Anthony, 1989).

The standard for achieving thermal comfort in a room using natural ventilation in a tropical climate region has been explained in ASHRAE Standard 55-2017, which states that the temperature range considered comfortable is between 23°C to 26°C, with a relative humidity level of 30% to 60% (ANSI/ASHRAE, 2017). In addition, the Decree of the Minister of Health No. 261/MENKES/SK/II/1998 also stipulates health criteria for achieving comfortable conditions indoors. According to this decree, the air temperature considered healthy for a room is between 18°C to 15-26°C, with a relative humidity ranging from 40% to 60%. By complying with these two standards, the room can achieve a level of thermal comfort that meets health and environmental requirements.

2) Comfort factors in space

According to Fanger (1972), thermal comfort conditions are also influenced by climate and personal factors. Climate factors that affect thermal conditions include air temperature, average radiation temperature, relative humidity, wind speed, and air

movement in space. Individual factors that determine comfortable temperatures are the type of activity and the type of clothing worn.

a. Air temperature

The air temperature between one region and another is very different. This difference is caused by several factors, such as the angle of sunlight, the height of a place, wind direction, ocean currents, clouds, and the duration of exposure. The units commonly used for air temperature are Celsius, Fahrenheit, Reamur and Kelvin. The comfort limits due to air temperature factors for equatorial regions are 19°C TE (lower limit) - 26°C TE (upper limit) (Lippsmeier, 1994). At a temperature of 26°C TE, humans generally start to sweat. At a temperature of 26°C TE – 30°C TE, human endurance and work ability begin to decline. The environmental temperature begins to be quite difficult to accept at a temperature of 33.5°C TE– 35.5°C TE, and at a temperature of 35°C TE – 36°C TE the environmental conditions can no longer be tolerated. Uncomfortable air conditions tend to reduce productivity levels, such as being too cold or too hot, whereas human work productivity can increase in comfortable (thermal) temperature conditions (Talarosha, 2005).

b. Air humidity and relative humidity

Air humidity is the water vapor content in the air. Air humidity becomes an important factor in thermal comfort when the air temperature approaches or exceeds the comfort threshold and the air humidity is more than 70% and less than 40%. In indoor conditions, this air humidity affects the release of heat from the human body. High air humidity will cause heat in the human body to be difficult to release, so this condition will create discomfort. To compensate for this high humidity condition, sufficient wind speed is needed in the room, while relative humidity is the ratio between the amount of water vapor in the air and the maximum amount of water vapor that can be accommodated in the air at a certain temperature. The factors that affect air humidity are solar radiation, air pressure, altitude, wind, air density, and temperature.

c. Wind velocity

Wind is moving air caused by the force resulting from differences in pressure and temperature (Satwiko, 2009:5). Wind speed in humid tropical climates tends to be very minimal. Wind speed generally occurs during the day or during the changing seasons. The role of this moving air is very helpful in accelerating the release of heat on the surface of the skin. Wind helps lift water vapor that inhibits the release of heat. However, if this wind is too strong, the heat released by the body becomes excessive so that a cold condition will arise which reduces thermal comfort.

d. Clothing insulation

Another factor that affects thermal comfort is the type and material of clothing used. One way for humans to adapt to the thermal conditions in their surroundings is by dressing, for example, wearing thin clothes in summer and thick clothes in winter. Clothing can also reduce the release of body heat. In the study of Henry and Nyuk (2004) on 'Thermal comfort for naturally ventilated houses in Indonesia' it was stated that room occupants can adapt to thermal conditions by adjusting the type of clothing to the existing climate conditions.

e. Activity.

Human activities will increase the body's metabolic process. The higher the intensity of the activity, the greater the increase in metabolism that occurs in the body, so that the amount of heat energy released is greater.

3) Characteristics of Dry Tropical Regions

a. Climate: The dry tropics are characterized by high temperatures and low rainfall. The average annual temperature is usually 20°C to 30°C, with little fluctuation between day and night. Annual rainfall is often less than 500 mm, and most of the rain occurs over a short period, usually during the short rainy season. Houghton (2009)
b. Vegetation: Vegetation in this area usually consists of shrubs, xerophytes, and trees that are resistant to drought. Examples are cacti and succulents that can store water Gao et al., (2015)
c. Impact on Human Life: The dry climate affects agricultural patterns, with irrigation practices often used to support agriculture. Communities living in this area usually develop agricultural techniques that are suited to the harsh environmental conditions Hassan et al.,(2017)

B. Teacher Job Stress

Etymologically, the term stress comes from the Latin wordstrictus" which means and indicates something that becomes narrow or narrow (Lindau, Almkvist & Mohammed, 2016). The term stress is also very popular in today's society and requires further discussion to explain such a broad problem in medical and psychological terms (Monroe & Slaviah, 2016).

Regarding the development of stress theory, Cannon, Selye, Lazarus, and Folkman (Lumban Gaol, 2016) are the main pioneers who developed stress theory, which is still the basis for stress research in human life.Although stress theory became increasingly

prominent in the social sciences in the 1950s, pioneered by Hans Selye (Kyriacou, 2001; Lumban Gaol, 2016), research on stress in the teaching profession actually began in the 1930s. Research on teacher stress began to develop several decades later, in the 1960s, and progressed rapidly in the 1990s (Kyriacou, 2001). Subsequent research has attempted to identify the causes, impacts, and management of stress in schools (Leach, 1984).In the field of education, Cambridge University researchers Chris Kyriacou and John Sutcliffe developed a model of teacher stress in 1978 (Kyriacou & Sutcliffe, 1978a).One year before this model was developed, Kyriacou and Sutcliffe published their first paper on teacher stress in 1977 (Kyriacou, 2001). They were also key pioneers who contributed to the development of the definition of stress among teachers, describing teacher stress as a condition that results in negative impacts experienced by teachers due to negative perceptions of the classroom environment (McCarthy, Lambert, & Reiser, 2014). In addition to the teacher stress model, Kyriacou and Sutcliffe (1978b) have also found various sources of stress experienced by teachers, namely time pressures, student misbehavior, and poor school ethos. From these works, they became the most well-known figures as the founders of teacher stress theory.The occurrence of stress can interfere/hinder teacher performance. Teacher performance is the ability of a teacher to carry out learning tasks at school and be responsible for students under his guidance by improving student learning achievement.Teacher work stresscan be caused by various factors, including an unsupportive physical environment. Research shows that high stress can disrupt teachers' mental and physical health, as well as reduce their motivation and performance.

C. Teacher Performance

The Impact of Thermal Comfort on Teacher Performance. Previous Research: Previous research shows that poor thermal comfort can affect productivity and health. A room that is too hot can result in decreased productivity and the body becomes more easily tired. Reny, CA (2020)

III. RESEARCH METHODOLOGY

Research design: This study uses a quantitative research design to measure the effect of thermal comfort in classrooms on the level of work stress and teacher productivity.

Environmental Parameter Measurement: The environmental parameters measured include temperature, humidity, and wind speed, PMV measurements are carried out: PMV values are calculated using a predetermined formula and measured directly in the classroom.

A. Method of collecting data:

The survey in this study was conducted by distributing questionnaires to all teachers of SDI Beru and Interviews: Data were obtained through surveys and interviews with teachers at SDI Beru. The survey was used to collect data on teachers' perceptions of thermal comfort, while interviews were used to obtain further information about their experiences in the classroom.

B. Preparation of Research Instruments and Data Collection

At this stage all instrument tools are prepared and arranged according to the situation and school environment. The software of the measuring instrument is installed to make it easy to input measurement data into the program. The instruments used are: Elitech Rc-4Hc Lcd Digital Temperature Humidity Data Logger, Verliant Heat Stress WGBT and Anemometer with Thermal Technology using a propeller sensor that converts propeller rotation into wind speed. These three tools are installed on the inside of the classroom (in the middle of the room) and on the outside of the classroom (by looking at the direction of the wind), while the questionnaire about teacher work stress was distributed to 16 (sixteen) teachers.

C. Questionnaire Design

Table 1. Questionnaire Design

Teacher Job Stress		**Thermal Comfort**
Physical Environment	Lighting	Temperature
	Noise	Humidity
	Cleanliness	Wind velocity
	Ventilation	Types of clothing
	Space Layout	Type of activity
	Use of Color	
	Supporting Facilities	
	Equipment Condition	
	Equipment Completeness	
	Job Security	

	Occupational Health	
Non-physical environment	School/foundation policy	
	Career development	
	Interpersonal relationships	
	Workload	
	Clarity of roles	
	Social Support	
Organization	Leadership	
	Organizational structure	
	Organizational Change	

D. Data analysis

Correlation Analysis: Correlation analysis is used to determine the relationship between PMV values and work stress levels and how they affect teacher performance.

Regression Analysis: Regression analysis was used to predict the level of work stress and teacher performance based on PMV values.

IV. RESULTS AND DISCUSSION

A. Research result

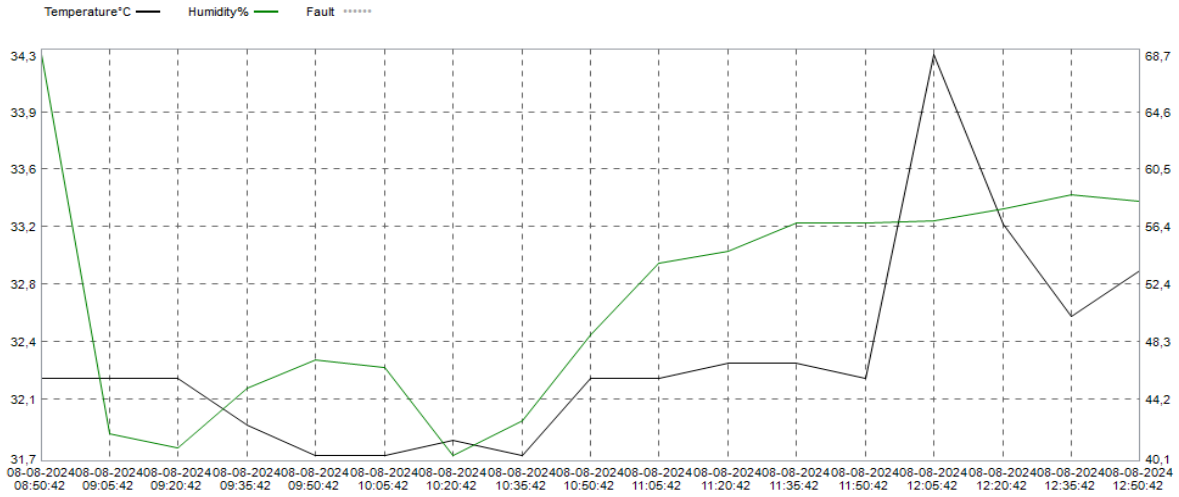

Figure 1 below shows:

PMV Measurement Results:

The measurement results in several classes and one of the classrooms at 08:41:45, the temperature was 30.7°C and the humidity was 64.0%. While at 12:56:45, the temperature was 33.3°C and the humidity was 54.2%. Based on the data, at 08:41:45, the thermal conditions can be considered slightly uncomfortable due to the temperature and humidity that are not ideal. At 12:56:45, the thermal conditions are very uncomfortable due to the very high temperature and humidity that are not ideal.The results of PMV measurements show that the PMV value in the SDI Beru classroom is outside the comfort range (-0.5 to +0.5). Most of the PMV values are above +0.5, indicating that the classroom is uncomfortable to use.

B. Research Results Using SPSS

1) Validity Test Results

In the validity test using SPSS software, there are 50 valid statements because the calculated r is greater than the table r of 0.361 or more, so it can be used for analysis of teacher work stress and thermal comfort experienced by teachers.

2) Reliability Test Results

Testing is done by one shot or one-time measurement. SPSS software provides results that a construct or variable is said to be reliable and acceptable if the alpha value is >0.6 (Ghoazali 2009:42) based on the results of the reliability test with the help of SPSS software shown in table 1:

Table 1. Reliability Test Results

Cronbach's Alpha	N of Items
.898	50

3) Normality Test Results

In the thermal comfort variable (X), to find out whether the data is normal or not, the Kolmogorov Smirnov formula is also used with the help of the IBM SPSS Release 25.0 program. The results of the normality test calculation on the thermal comfort variable can be seen in the following table 2:

Table 2. Normality Test Results

		Unstandardized Residual
N		88
Normal Parameters	Mean	.0000000
	Std. Deviation	13.71126442
Most Extreme Differences	Absolute	.056
	Positive	
	Negative	-.056
Kolmogorov-Smirnov Z		.529
Asymp. Sig. (2-tailed)		.943

a. Predictors: (Constant), THERMAL COMFORT
b. Dependent Variable: WORK STRESS

Based on the results above, the variable Based on table 2 above, the significance value of the resulting thermal comfort variable (X) (Asymp.sig = 0.943) is greater than the alpha value (a = 0.05). Thus, it can be concluded that the data from the thermal comfort variable (X) is normally distributed.

4) Linearity Test

Linearity Test is used to determine whether or not the relationship between independent variables and dependent variables in a study is linear. The relationship between variables is said to be linear if sig. is greater than or equal to 0.05. The calculation of the linearity test in this study uses the SPSS Release 25.0 program. The results of the linearity test calculation can be seen in table 3:

Table 3. Linearity Test Results

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
WORK STRESS * THERMAL COMFORT	Between Groups	(Combined)	9175.579	16	573,474	3.238	.000
		Linearity	5393.005	1	5393.005	30,454	.000
		Deviation from Linearity	3782.574	15	252,172	1,424	.160
	Within Groups		12573.319	71	177,089		
	Total		21748.898	87			

Based on table 3 above, the results of the analysis show that there is a significant linear relationship between work stress and thermal comfort (F Linearity = 30.454; Sig Linearity = .000).

5) TestHypothesisPartially (t-test) t-test

It is a hypothesis test that will be used to determine the effect of independent variables partially on the dependent variable (thermal comfort) on the dependent variable (teacher work stress) by assuming that other independent variables are considered constant. The hypothesis proposed in the partial test (t-test) in this study is the effect of thermal comfort variables on teacher

work stress. The t-test (t-test) of the results of this calculation is then compared with the t table using an error rate of 0.05 (5%). The criteria used are as follows: 1) H0 is accepted if the value$thitung \leq ttabel$or sig value > α 2) H0 is rejected if the value$thitung \geq ttabel$or sig value < α

6) The effect of thermal comfort on teacher work stress

Table 4. The effect of thermal comfort on teacher work stress

Coefficients[a]

Unstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
85,403	12.925		6,608	.000
2.002	.376	.498	5.325	.000

Based on table 4 above, the results of the simple linear regression equation are as follows: Y = 85.403 + 0.498X
Based on the calculation, it can be seen that the regression coefficient value of the thermal comfort variable (X1) is 0.498 with a positive sign at sig 0.000 which is smaller than 0.05, namely 0.000 <0.05. The regression coefficient value of the thermal comfort variable (X1) of 0.498 indicates that there is a positive relationship between thermal comfort and teacher work stress. This means that every one unit increase in thermal comfort will be associated with a 0.498 unit increase in the measured variable (teacher work stress). The significance value (p-value) of 0.000 is smaller than 0.05 (0.000 <0.05). This shows that the results are statistically significant. In other words, there is strong evidence to state that thermal comfort affects teacher work stress. So it can be interpreted that thermal comfort has a positive effect on teacher work stress. This shows that thermal comfort in the classroom will affect the level of teacher work stress.

7) The relationship between thermal comfort and teacher work stress

The relationship between thermal comfort and teacher work stress can be seen in table 5 below:

Table 5. Relationship between thermal comfort and teacher work stress

Correlations

	WORK STRESS	THERMAL COMFORT
Correlation Coefficient	1,000	.493**
Sig. (2-tailed)	.	.000
N	88	88
Correlation Coefficient	.493**	1,000
Sig. (2-tailed)	.000	.
N	88	88

**. Correlation is significant at the 0.01 level (2-tailed).

The positive correlation between work stress and thermal comfort indicates that the higher the thermal comfort, the lower the work stress. The correlation value of 0.493 indicates that the relationship is quite strong. The significance value of 0.000 indicates that the results are very significant and cannot be ignored. Thus, the correlation table above shows that there is a significant and positive relationship between thermal comfort and teacher work stress, which is important to consider in efforts to improve a comfortable working environment for teachers. The survey results show that most teachers feel uncomfortable in the classroom. This perception is consistent with the results of PMV measurements which show uncomfortable thermal conditions.

V. CONCLUSION AND SUGGESTIONS

A. CONCLUSION

Based on the results of the study, it was obtained that the temperature and humidity measurement data obtained from the measuring instrument showed that the temperature in the classroom ranged from 27.0°C to 33.3°C with humidity varying between

54.2% to 71.1%. Classroom thermal comfort has an effect and is related to teacher work stress. Thermal comfort in the classroom, which includes temperature, humidity, and air flow, plays an important role in creating a conducive learning environment.

PMV value is used to evaluate thermal comfort. The ideal PMV value ranges from -0.5 to +0.5, where 0 indicates neutral conditions. Temperature conditions higher than 26°C can affect teacher comfort and productivity. With the maximum temperature recorded reaching 33.3°C, it is likely that this condition is outside the comfort range, which can cause discomfort for teachers. The results of the PMV calculation are supported by the results of the questionnaire through the SPSS program that the regression coefficient value of the thermal comfort variable (X) of 0.498 indicates that there is a positive relationship between thermal comfort and teacher work stress. This means that every one unit increase in thermal comfort will be associated with a 0.498 unit increase in the measured variable (teacher work stress). The significance value (p-value) of 0.000 is smaller than 0.05 (0.000 < 0.05). This shows that the results are statistically significant. In other words, there is strong evidence to state that thermal comfort affects teacher work stress. There is a significant and positive relationship between thermal comfort and teacher work stress. Improving thermal comfort in classrooms can help reduce teachers' work stress, which is important for improving their performance and well-being.

Research shows that poor thermal comfort can reduce teacher concentration and productivity. Discomfort due to high temperatures can cause fatigue, stress, and decreased motivation. When teachers feel uncomfortable, they tend to experience decreased performance in teaching and interacting with students, which has a negative impact on the learning process. There is a significant relationship between the level of thermal comfort and teacher productivity. A thermally comfortable environment can increase teacher concentration and motivation, thus having a positive impact on the quality of teaching and student learning outcomes. Conversely, uncomfortable thermal conditions can cause work stress, fatigue, and decreased teacher productivity.

B. SUGGESTIONS

Suggestions that researchers can provide include:

1) Temperature and Humidity Control: Optimal temperature and humidity control is necessary to achieve comfortable thermal conditions.
2) Using cross ventilation and heat-reflecting materials can help reduce indoor temperatures.
3) Use of Temperature and Humidity Meters: Using accurate temperature and humidity meters can help in measuring the thermal conditions in the classroom.
4) Conduct regular monitoring of temperature and humidity in the classroom to ensure conditions remain within a comfortable range. This way, thermal comfort in the classroom can be improved, which in turn will support teacher and student productivity and create a better learning environment.

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