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Post-Occupancy Evaluation (POE) theory room of SMK in Bantul assessed from lightning and ventilation

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ABSTRACT

This study Post-Occupational Evaluation (POE), aims to determine whether the natural lighting and ventilation openings in theoretical rooms at SMK XYZ have met the standards or not. The review of technical aspects focused on lighting and ventilation issues. This research is descriptive, evaluative, with the POE method at the investigative level, making 13 theoretical rooms as research objects and 156 students or 12 students per class as research subjects. The research instrument is a measuring instrument plus a questionnaire as data to strengthen the study results. Data collection techniques with observation and recording of primary data and secondary studies. The data analysis technique used descriptive quantitative. The condition of the theoretical space at SMK XYZ for the KBM process does not meet standards, such as natural lighting of the theoretical room in 11 of the 12 existing rooms; inlet and outlet area, the elevation of ventilation holes at the inlet throughout the theory room.

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INTRODUCTION

The school line education unit must provide facilities and infrastructure that support the teaching and learning process (KBM), as stated in Law of the Republic of Indonesia Number 20 of 2003 concerning the education system Article 45 paragraph 1 states that every formal and non-formal education unit provides facilities and infrastructure that meet educational needs in accordance with the growth and development of the physical, intellectual, social, emotional, and psychological potential of students. In this way, both students and teaching staff can carry out the teaching and learning process effectively, so that maximum student learning achievement can be achieved. One of the facilities and infrastructure needed is a comfortable theory room and meets the standard needs of its users (Panero & Zelnik, 2003).

It is undeniable that a comfortable theoretical space will make the teaching and learning process more conducive (Watson, 2003). A conducive teaching and learning process will certainly have a good impact on student learning outcomes (Doelle, 1993; Watson, 2003). The conducive physical condition of the study room includes; adequate lighting, good air circulation, minimal noise, and adequate facilities and infrastructure to support a study group. The physical condition of the theoretical space largely has an influence on the possibility of disturbance. Inadequate natural lighting, room temperature that is too hot can reduce most of the students' ability to concentrate on the subject matter, although this often escapes the attention of teachers and school administrators (Septiani, 2015).

As is the case in SMK XYZ, based on observations made, the KBM process in the theory room tends to run less conducive. The teaching and learning activities in the theory room are disturbed by the heat and stuffiness in the theory room during the day. Even though teak trees surround the school environment, some theory rooms are very dark even during the day and have to use lighting from lamps. These problems affect the teaching and learning process, which becomes less conducive.

Based on these brief observations, a review or evaluation of the theoretical space at SMK XYZ is needed, which is expected to provide knowledge to related parties to be improved in the future. It is planned that the study on this object will be carried out using the POE method. According to Sudibyo (in Prawitasari, 2019), Post Occupancy Evaluation (POE) is an activity in the form of reviewing (evaluating) the buildings and the built environment that has been inhabited. This evaluation serves to determine the actual condition of the building in the field after being occupied. Then the results will be used as input and improvements for better building designs in the future. Post-Occupational Evaluation (POE) is divided into three main problems, namely technical, functional and behavioral (Elfajri, 2016; Raihan, 2018).

The technical aspects of POE itself include structure, sanitation, ventilation, fire safety, electrical, exterior walls, interior finishing, roofing, acoustics, lighting, and environmental control systems (Preiser et al., 2015). Judging from the problems in the theoretical room at SMK XYZ, POE can examine problems in technical aspects, which include lighting and ventilation. In addition, there are three levels in conducting POE. The first indicates the success and failure of the building, carried out in a short time (approximately 3 hours) (Cannon & Edmondson, 2005). The second is investigative, namely identifying the success and failure of the building, then the data is compared with applicable standards, usually done for 2-4 weeks. Third diagnostic using data collection techniques and perfect analysis techniques that produce investigative and indicative POE (Gonzalez-Caceres et al., 2019). Sometimes evaluations of this level attempt to develop results that indicate relationships between variables, monthly to annual time. In this research, the aspects that will be reviewed are technical and functional at the indicative level. Evaluation of technical aspects will focus on the problem of natural lighting and ventilation (Hauge et al., 2011).

The lighting that will be studied is natural lighting. Lighting is one thing that is very important for humans to get a safe and comfortable living environment, according to Satwiko (2008), the sun is the main source of natural light for the earth. Natural lighting in the building is used to illuminate the building from sunrise to sunset. Natural light from the sun is also good for human health. Natural lighting is divided into two, sunlight, direct sunlight, which generally has a narrow spread of light and high intensity. Daylight, indirect sunlight, atmospheric particles, including clouds that scatter sunlight onto the earth. Each room certainly has different light intensity requirements. Therefore it is necessary to have an appropriate lighting system according to the needs of the space.

Table 1. Standards for Requirements for the Light Level of Each Room (Lux)

No.	Activities (Office and School)	Illumination (Lux)
1	Office	300
2	Conference room	300
3	Ordinary public office	500
4	Indoor general office	1000
5	General office drawing room	1000

The natural daylight factor (FPASH) at a point in the room is the ratio between the horizontal illumination in the indoor work area (Ei [lux]) to the horizontal illumination in the outdoor open field (Eo [lux]) at the same time. Minimum FPASH measurements are carried out at one main measuring point (TUU) and two side measuring points (TUS), all at the height of 75 cm from the floor and at a distance of d/3 (d= room depth) from the plane where there is a light hole. TUU is in the middle of the two side walls, while TUS is each 0.5 meters from the nearest sidewall.

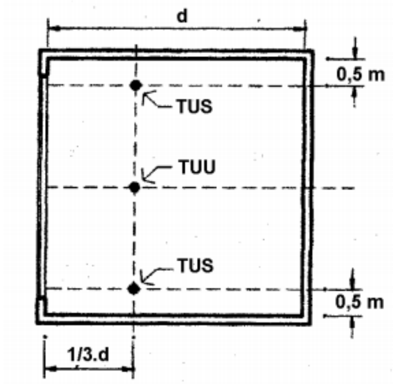

Figure 1. TUU, TUS, and d

In addition to the ventilation lighting in the SMK XYZ, it is studied to find out whether it has been made and functions effectively to circulate air in the theoretical room. Ventilation itself is the flow of air, both in open and closed spaces, according to Satwiko (2008), based on the condition of the theoretical room in SMK XYZ, which not all classes have a fan that functions properly review will focus more on natural ventilation. Natural ventilation is the process of changing room air by fresh air from outside without the help of mechanical equipment (Satwiko, 2008). The things that will be reviewed on the ventilation holes in the theory room are the orientation of the openings, the position or elevation of the ventilation holes, the dimensions of the ventilation holes, the type of openings, and the direction of the openings.

The position of the ventilation hole that functions for the entry of air (inlet) should be placed at the height of the human activity. One of the good openings is that there must be cross ventilation. By providing openings on both sides of the dining room will provide an opportunity for air to flow in and out. At the same time, the ventilation holes that function for the exit of air (outlet) should be placed higher (above the height of human activity) so that hot air can exit easily without being mixed with fresh air entering from the inlet. The height of human activity in the room is approximately 60-80 cm (sitting activity) and 100-150 cm (standing activity) (Mediastika, 2005). To reduce indoor air temperature, massive wind movement is needed (Linden, 1999). With the difference in inlet and outlet openings, the air pressure outside and inside the room changes to enter the room.

Table 2. Ratio of Increase in Aperture Dimensions

No.	Ratio	Enhancement (%)
1	1 : 1	0
2	1,1 : 1	17.5
3	2 : 1	26

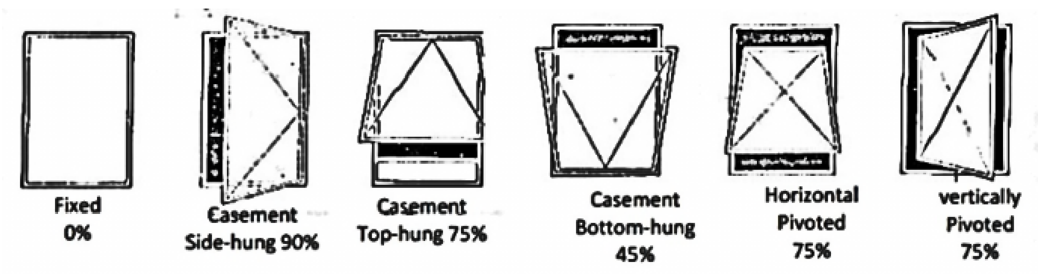

Figure 2. Aperture Design

Based on SNI 03-6572-2001, the natural ventilation provided must consist of permanent openings, windows, doors, or other facilities that can be opened with the following criteria: 1.) The number of ventilation openings is not less than 5% of the floor area of the room that requires ventilation; and 2.) The direction faces a walled courtyard of a suitable size or an area that opens up. In addition, the type of opening also affects the direction of the air in the room. A good window type is one that can circulate air with the largest percentage, namely the casement side-hung type with a percentage value of 90% (Sari et al., 2021).

RESEARCH METHOD

This study uses a descriptive evaluative at the investigative level in the POE method with a quantitative approach. This research was conducted over a period of one month, from April 26 to May 26, 2018. The population of this research is all the theoretical rooms in SMK XYZ, as many as 13 rooms. Data collection techniques by observing and recording primary data are measurements, data depictions or photo recordings of the conditions and specifications of theoretical spaces, and secondary studies using library documents and documents regarding existing theoretical spaces as study material. This research instrument uses measuring instruments in the form of a 3 m and 50 m meters, camera, lux meter (Lutron LX-107). The data analysis technique used descriptive quantitative.

RESULT AND DISCUSSION

Daylight, the measurement of the brightness of natural lighting (illumination) in theoretical rooms at SMK XYZ, was carried out at 07.00 AM (6.50 - 07.10 AM) WIB and 12.00 PM (11.00 AM - 12.00 PM) WIB and was taken from light sources from the inlet and outlet openings. The measurement uses a Luxmeter with the Lutron LX-107 brand by choosing the smallest scale, which is 2000 in LUX units. Lighting data retrieval is limited to Luxmeter measurement with one-time data collection without considering weather conditions and moon position. The measurement results are presented in the following Table 3.

Table 3. Natural Lighting Measurement Results at 7.00 AM (6.50 - 07.10) GMT+7

Room	lane	Illumination E (LUX)		
		TUS 1 (Side Measuring Point) 1	TUU (Main Measuring Point)	TUS (Side Measuring Point) 2
R1	North	160	500	220
	South	84	111	115
R2	North	98	118	58
	South	44	50	53
R3	North	10	47	32
	South	8	16	17
R4	North	0	0	0
	South	0	0	0
R6	East	22	16	14
	West	25	32	19
R7	East	17	14	13
	West	16	18	20
R8	East	59	30	32
	West	33	34	19
R9	West	18	28	23
	East	8	12	22
R10	West	10	10	10
	East	4	5	3
R11	East	123	186	115
	West	29	23	20
R12	East	37	35	62
	West	5	3	0
R13	South	55	32	34
	North	44	143	124

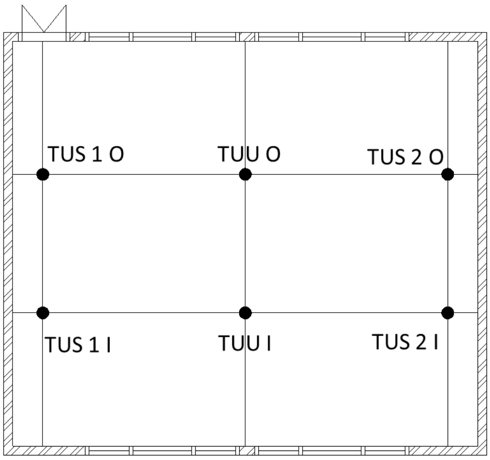

Figure 3. TUS and TUU Data Collection Points

The data from the measurements in the field are classified into the following four categories, such as the situation felt during the research: Dark (Da) < 50 Lux, Dim (Di) 50-250 Lux, Bright (B) 250 – 350 Lux, Very Bright (VB) >350 Lux. The standard of room lighting, according to Hartono Poerbo (1992:61) for schools is 300 Lux, but in this case, it is estimated that a comfortable room lighting for learning activities in a theoretical room is between 250 Lux to 350 Lux. Based on measurements using a Lux meter for natural lighting at 07.00 WIB, all the rooms that became the object of the study did not meet the lighting standards, four rooms were classified as dim, and eight rooms were classified as dark.

Table 4. Average Natural Lighting from Outlet and Inlet Natural Lighting at 7.00 AM (6.50 AM - 07.10 AM) GMT+7

Room	Illumination E (LUX)			
	lane	TUU Average	TUU average O and I	Category
R1	O	293.33	198.33	Di
	I	103.33		
R2	O	91.33	70.17	Di
	I	49		
R3	O	29.67	21.67	Da
	I	13.67		
R4	O	0	0.00	Da
	I	0		
R6	O	17.33	21.33	Da
	I	25.33		
R7	O	14.67	16.33	Da
	I	18		
R8	O	40.33	34.50	Da
	I	28.67		
R9	O	23	18.50	Da
	I	14		
R10	O	10	7.00	Da
	I	4		
R11	O	141	82.67	Di
	I	24		
R12	O	44.67	23.67	Da
	I	2.67		
R13	O	40.33	72.00	Di
	I	103.67		

Table 5. Average Natural Lighting from Outlet and Inlet Natural Lighting at 12.00 PM (6.50 AM - 07.10 AM) GMT+7

Room	E illumination (LUX)			
	lane	TUU Average	TUU average O and I	Note.
R1	O	978	847.165	VB
	I	716.33		
R2	O	696	540.665	VB
	I	385.33		
R3	O	57.67	37.67	Da
	I	17.67		
R4	O	0	0	Da
	I	0		
R6	O	31.33	31.83	Da
	I	32.33		
R7	O	55.33	45.83	Da
	I	36.33		
R8	O	101.67	78.335	Di
	I	55.00		
R9	O	122.33	85.33	Di
	I	48.33		
R10	O	61.33	39,665	Da
	I	18		
R11	O	102.33	79.83	Di
	I	57.33		
R12	O	89.33	70	Di
	I	50.67		
R13	O	274.67	286.67	B
	I	298.67		

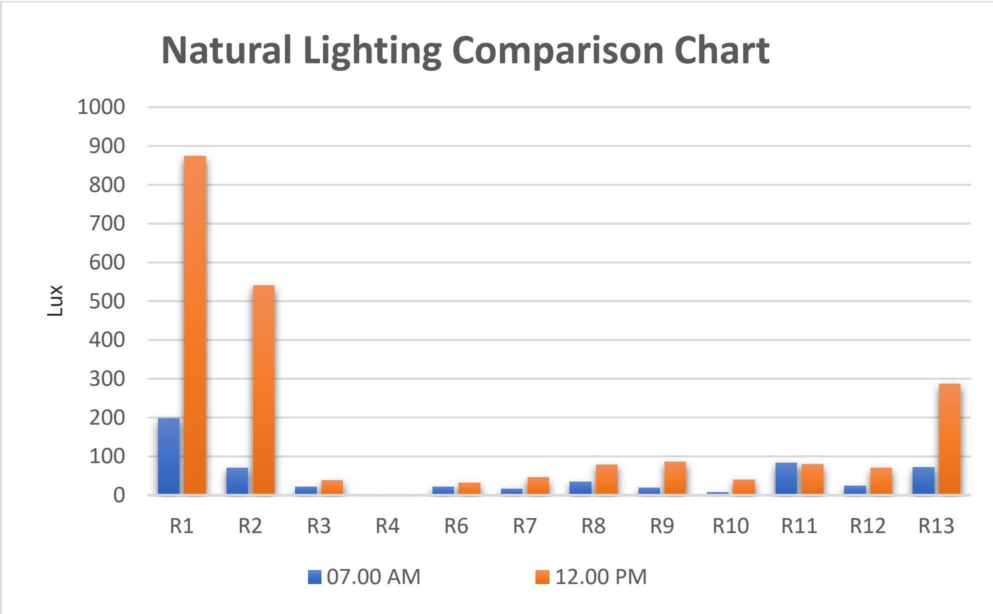

Figure 4. Graph of Comparison of Natural Lighting Measurement Results at 07.00 AM (GMT+7) with 12.00 PM (GMT+7)

The standard of room lighting, according to Poerbo (1992) for schools is 300 Lux, but in this case, it is estimated that a comfortable room lighting for learning activities in a theoretical room is between 250 Lux to 350 Lux. Based on measurements using a Lux meter for natural lighting at

07.00 WIB, all the rooms that became the object of the study did not meet the lighting standards, four rooms were classified as dim, and eight rooms were classified as dark.

Measurements at the time range at 12.00 WIB obtained the results of 2 rooms, namely room R1 and R2 exceeding the lighting standard, excess natural light that enters brings heat which affects the room's stuffiness, even before 7.00 it feels hot as respondents stated in the Questionnaire. R13 already meets lighting standards, and R3, R4, R6, R7, R8, R9, R10, R11, and R12 spaces do not meet room lighting standards. The analysis results above are only the theoretical room R13 or only 1 (8.33%) of the total 12 rooms at 12.00 WIB that meet the comfort standard.

The graph of the comparison of the results of natural lighting measurements at 07.00 WIB with 12.00 WIB shows an increase in the strength of the lighting in each room, except for R11 there is a decrease and in-room R4 it does not show an increase in lighting strength.

Table 6. Natural Lighting Measurement Results 12.00 Hours (11.00 AM - 12.00 PM) GMT+7

Room	Illumination E (LUX)			
	lane	TUS 1	TUU	TUS 2
R1	O	811	1158	965
	I	667	626	856
R2	O	617	864	607
	I	384	412	360
R3	O	17	101	55
	I	15	20	18
R4	O	0	0	0
	I	0	0	0
R6	O	38	31	25
	I	33	30	34
R7	O	51	56	59
	I	31	40	38
R8	O	110	108	87
	I	65	54	46
R9	O	85	127	155
	I	34	47	64
R10	O	68	52	64
	I	17	21	16
R11	O	133	95	79
	I	60	69	43
R12	O	115	87	66
	I	60	56	36
R13	O	334	292	198
	I	248	342	306

R : Room
TUU : Main Measuring Point
TUS : Side Measuring Point
I : Inlet
O : Outlet

The type of window used is a top-hug casement that can circulate air with a percentage of 70%. The window elevation in the table is the window elevation from the floor. This ventilation data retrieval is to find out how influential ventilation is on the hot air temperature in theoretical rooms at SMK XYZ. This ventilation review is limited to the opening area and opening height without other data on thermal comfort, namely air humidity, air temperature, wind speed, and clothing.

Table 7. Inlet Dimensions

R	Inlet			
	Length (cm)	Width (cm)	Elevation (cm)	Amount
R1	75	98	102	6
R2	75	98	102	6
R3	68	98	135	6
R4	68	98	135	6
R5	-	-	-	-
R6	68	98	130	6
R7	68	98	130	6
R8	68	98	130	6
R9	68	98	113	6
R10	68	98	113	6
R11	68	98	116	6
R12	68	98	116	6
R13	68	98	125	6

Table 8. Outlet Dimensions

R	Outlet window			
	Length (cm)	Width (cm)	Elevation (cm)	Amount
R1	75	98	102	4
R2	75	98	102	4
R3	70	60	143.5	4
R4	70	60	143.5	4
R5	-	-	-	-
R6	70	60	144	4
R7	70	60	143	4
R8	70	60	143	4
R9	70	60	138	4
R10	70	60	138	4
R11	70	60	133	4
R12	70	60	133	4
R13	70	60	140	4

Table 9. Area of Aperture in Each Theory Room (Inlet)

R	Inlet			
	Length (cm)	Height (cm)	Amount	Ventilation area (m2)
R1	75	98	6	4.41
R2	75	98	6	4.41
R3	68	98	6	4
R4	68	98	6	4
R6	68	98	6	4
R7	68	98	6	4
R8	68	98	6	4
R9	68	98	6	4
R10	68	98	6	4
R11	68	98+40	6	6.45
R12	68	98+40	6	6.45
R13	68	98	6	4

Table 10. Area of Aperture in Each Theory Room (Outlet)

R	Outlet			Ventilation area (m2)	Inlet+Outlet Area (m2)
	Length (cm)	Height (cm)	Amount		
R1	75	98	4	2.94	7.35
R2	75	98	4	2.94	7.35
R3	70	60	4	1.68	5.68
R4	70	60	4	1.68	5.68
R6	70	60	4	1.68	5.68
R7	70	60	4	1.68	5.68
R8	70	60	4	1.68	5.68
R9	70	60	4	1.68	5.68
R10	70	60	4	1.68	5.68
R11	70	60+40	4	3.36	9.81
R12	70	60+40	4	3.36	9.81
R13	70	60	4	1.68	5.68

The area of the opening in the inlet is larger than the outlet in the entire theoretical space. It is less effective for the entry and exit of the wind in the space because it makes the wind speed in the room low, which affects the stuffiness of the theoretical room. It would be better if the inlet opening area was smaller so that the wind movement would be more massive to lower the indoor air temperature.

Table 11. Opening Presentation Present

R	room area (m2)	Ventilation (m2)	Percentage (%)	Standard (%)	Note
R1	60.92	7.35	12.07	5	Fulfill
R2	60.66	7.35	12.12	5	Fulfill
R3	61.29	5.68	9.27	5	Fulfill
R4	61.15	5.68	9.29	5	Fulfill
R6	60.78	5.68	9.35	5	Fulfill
R7	60.44	5.68	9.40	5	Fulfill
R8	60.26	5.68	9.43	5	Fulfill
R9	58.70	5.68	9.68	5	Fulfill
R10	58.67	5.68	9.68	5	Fulfill
R11	69.48	9.81	14.12	5	Fulfill
R12	69.72	9.81	14.07	5	Fulfill
R13	61.12	5.68	9.29	5	Fulfill

Based on the calculation of the percentage of the opening area of the entire theoretical space, which is the object of research, the overall minimum standard of openings is 5%, so all theoretical spaces that are the object of research at SMK XYZ have met the standards of SNI 03-6572-2001. Elevation of ventilation holes that function for air entry (inlet) should be placed at the height of human activity. Ventilation holes that function for the exit of air (Outlet) should be placed higher (above the height of human activity) so that hot air can exit easily without being mixed with fresh air entering from the inlet. The height of human activity in the room is approximately 60-80 cm (sitting activity) and 100-150 cm (standing activity).

The results of the comparison of data in the field with the standard show that the height of the entire inlet opening exceeds the standard, and the outlet opening meets the standard. The inlet opening that exceeds the user's activity (sitting activity) has an impact on the wind from the inlet flowing above human activities and cannot reach human activities below it.

Table 12. Ventilation Hole Elevation (Inlet)

Room	*Inlet*		
	Height (cm)	Standard(cm)	Note.
R1	102	60 – 80	Exceed
R2	102	60 – 80	Exceed
R3	135	60 – 80	Exceed
R4	135	60 – 80	Exceed
R6	130	60 – 80	Exceed
R7	130	60 – 80	Exceed
R8	130	60 – 80	Exceed
R9	113	60 – 80	Exceed
R10	113	60 – 80	Exceed
R11	116	60 – 80	Exceed
R12	116	60 – 80	Exceed
R13	125	60 – 80	Exceed

Table 13. Ventilation Hole Elevation (Outlet)

Room	Outlet		
	Height (cm)	Standard(cm)	Note.
R1	102	>80	Fulfill
R2	102	>80	Fulfill
R3	143.5	>80	Fulfill
R4	143.5	>80	Fulfill
R6	144	>80	Fulfill
R7	143	>80	Fulfill
R8	143	>80	Fulfill
R9	138	>80	Fulfill
R10	138	>80	Fulfill
R11	133	>80	Fulfill
R12	133	>80	Fulfill
R13	140	>80	Fulfill

In rooms R1 and R2, the inlet and outlet openings are the same height, resulting in hot air not being able to escape easily and possibly being mixed with fresh air entering from the inlet. The same aperture height was identified as a result of the stuffiness of the theoretical space at R1 and R2.

As for the room that does not meet the standard of room lighting for schools, it is necessary to add artificial lighting in the form of lights. The addition of artificial light needs to be taken into account in order to obtain sufficient lighting results for the teaching and learning process in schools. For a room that gets excessive lighting, you can add vegetation to the front of the room. Vegetation is useful for blocking some of the light that will enter, can also reduce the heat of natural light from the sun and as a barrier from noise. Vegetation placement is recommended along the front area of space R1, R2, R6, R7, R8, R9, R10, R11, R12, and R13. In addition, it is also on vacant land facing R2, R11, and R12. The ventilation that has been installed cannot be changed. Therefore, artificial ventilation in the form of a fan or air conditioner will greatly help reduce the stuffy air in the room.

In order to meet natural lighting as needed, it is necessary to design natural lighting according to the SNI Guidelines for natural lighting procedures in buildings, 2001. The placement of the theoretical room should be avoided from aisles that are closed on two sides of the area where light enters because the gaps in the entry of natural lighting are more a little. The placement of ventilation openings for light in the theory room should not be in direct contact with open spaces without barriers (open fields, vacant land) because the incoming light is not filtered. Solar heat may enter the room directly and make the room hot. If you are forced to face an open space, then you should be given vegetation as a filter for excess heat and light.

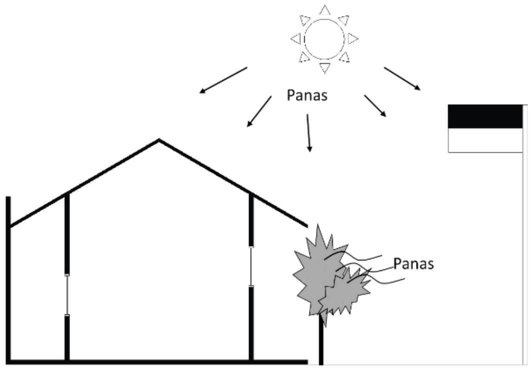

Figure 5. Illustration of Ventilation Openings Directly Opposite The Field with Vegetation

The theoretical space must be placed east-west so that in the morning and evening, sunlight does not enter directly into the theoretical space. Direct light that enters causes excessive heat and lighting in the theory room. Therefore it is necessary to avoid laying the building that functions as a north-south longitudinal theory room. The location of the SMK XYZ building is in the southern part of the equator, so the building located in the east-west direction gets direct light only from the north so that the handling of excess lighting in the theoretical room will be more efficient because it only focuses on the north.

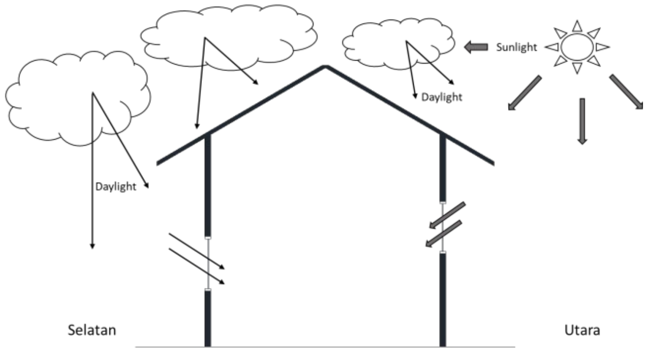

Figure 6. East-West Longitudinal Building

The position of the ventilation hole that functions for the entry of air (inlet) at SMK XYZ is located above human activities so that the incoming wind cannot reach humans in the room. In future developments, the position of the inlet ventilation hole should be placed at the height of human activities and the outlet should be placed higher (above the height of human activity) so that hot air can exit easily without being mixed with fresh air entering from the inlet.

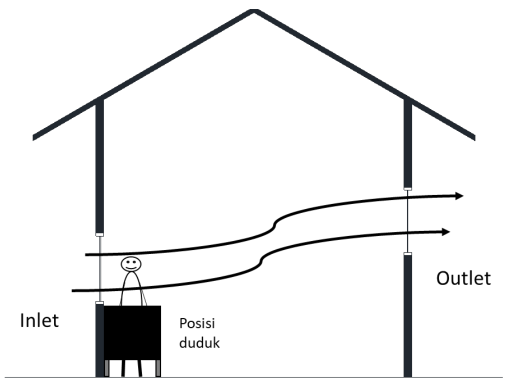

Figure 7. The Position of The Inlet is Located at The Height of Human Activity

In the case that occurred in SMK XYZ, the inlet is larger than the outlet. The movement of the wind in the room should be more massive. The inlet ventilation hole should have smaller dimensions to reduce the air temperature in the room (Zhang et al., 2016).

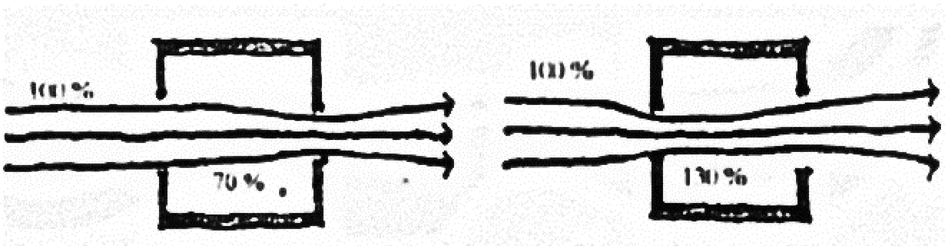

Figure 8. Differences in Inlet and Outlet Dimensions Affect Wind Speed in Buildings

CONCLUSION

Based on the data in this study, it can be said that there are still many theoretical spaces that do not meet the standards, such as; natural lighting of the theoretical room in 11 of the 12 existing rooms; Inlet and Outlet area; Elevation of ventilation holes at the inlet throughout the theory room. Students can directly feel this during the teaching and learning processeThis resulted in the teaching and learning process because the class was not conducive. In addition, the process of delivering material from the teacher to students is not optimal because the focus of students is divided. Previous research has been done by other researchers regarding thermal comfort in the image space in one of the vocational schools. The research was conducted because, at certain hours, there was an increase in temperature in the drawing practice room. This is certainly very disturbing to the comfort of students when drawing activities.

This kind of research will be very meaningful for repairing and overcoming the occurrence of similar problems in the future, which are stated in the following curative and preventive suggestions: 1.) Curative Advice, with this post-occupancy evaluation research on the theoretical room at SMK XYZ, the addition of lighting facilities is a curative step towards rooms that lack natural lighting. Then, vegetation can be added in front of the room as a light barrier for rooms that receive excess lighting and reduce the incoming heat. For thermal comfort, it is better to add an air conditioner or fan to cope with a room that is too hot. Equipment replacement also needs to be done gradually so that students also feel comfortable when using it. In addition, it also needs to rearrange the furniture and function of the room. As much as possible, the workshop space is kept away from the theory room so that the teaching and learning process is not disturbed by noise from the workshop; and 2.) Preventive Advice, the design of lighting needs, ventilation, layouts in buildings should be guided by existing standards to avoid the same lighting problems in the next building construction.

The limitation of this study is that when the research process coincides with the time of the end of the semester exam, which affects the measurement data, there is a need for further research on the teaching and learning process to obtain more accurate and targeted data..

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