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A REVIEW ON THERMAL COMFORT IN EDUCATIONAL BUILDINGS OF SOUTHEAST ASIA REGION.

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Abstract

The thermal comfort in a classroom plays an important role in students' life as it affects the comfort, health as well as the students' learning performance. Students spend most of their time at school and in the classroom. Therefore, it is crucial that the thermal comfort in the classroom must be considered carefully because of the high occupant density and the negative influences that unsatisfactorily thermal environments may have on learning and students' performance. This paper presents an overview of thermal comfort studies in educational buildings over the last twenty years that were carried out in countries within the South East Asia region. These countries have the same tropical climates which are generally warm all year round. The study is divided into two sections; the first section reviews the variables which are measured to determine thermal comfort and the second reviewing study results based on the educational stage, and the applied thermal comfort approach. Discussion on variables and parameters will help to outline the priorities for the future research agenda in this field. Thus, this study will provide robust evidence that there is a need for thermal comfort studies for students with different ages and different stages of their education.

Keywords: thermal comfort, educational building, learning performance, South East Asia region, systematic literature review.

1.0 INTRODUCTION

Students spend more time in educational building, school, or class than in any other building. Therefore, the environmental condition of the school is considered as important because it influences not only comfort and health, but also working and learning efficiency of the students. Jiang, Wang, Liu, Xu, & Liu (2018) reported that high and low temperature can cause thermal discomfort and it negatively impacts students' learning performances and their wellbeing. Mishra & Ramgopal (2015) reported that the thermal environment in the classroom will affect the ability of students to grab classroom instruction.

This paper focuses on the review of literature pertaining to the thermal comfort studies in educational buildings in countries in the South East Asia region that share the same tropical climate which is generally warm throughout all year round. Many studies have been conducted to investigate thermal comfort within these countries. However, there is still a lack found in studies of classroom thermal comfort. Therefore, this paper will review previous literature regarding thermal comfort in two sections, which are;

- The variables in measuring thermal comfort in an educational building.
- Reviewing study results based on the educational stage, and the applied thermal comfort approach.

2.0 LITERATURE REVIEW

2.1 Thermal comfort in educational building

The primary goal of educational building is to provide students from age 2 to 26 years old with favorable mood or atmosphere in classrooms to ensure effective teaching and learning process to take place. Across the globe, the educational system involves different stages and each stage takes a certain amount of time in the classrooms more than any other buildings. Therefore, educational buildings, especially the classrooms, should have the characteristics that provide stimulating environments to enhance the learning process.

A lot of published research has proven that there is a strong correlation between classroom air quality and the thermal comfortness with student's performance and well-being. Jiang, Wang, Liu, Xu, & Liu (2018) found that high and low temperature can cause thermal discomfort and negatively affects students' learning performances and their wellbeing. Mishra and Ramgopal (2015) reported that thermal environments in the classroom will affect the students' ability to grasp instruction.

2.2 Thermal comfort in Educational Building in South East Asia

Southeast Asia is composed of eleven countries with diversity in religion, culture and history. These countries are Brunei, Myanmar, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand and Vietnam. The climate of Southeast Asia can be generally described as tropical, meaning that the weather tends to be the hot and humid most part of the year. A significant number of thermal comfort studies carried out in recent decades have been devoted to determine thermally comfortable temperatures in various settings within this region. However, there is still lack found since most of the studies were focusing on residential building and adult comfort level only**. Table 1** shows a summary of the thermal comfort studies in educational building for the past 10 years.

3.0 METHODOLOGY

A desktop study was conducted to search the relevant article via online scientific journals publications in Building and Environment which includes Scopus and ScienceDirect. The keywords used were "thermal comfort" and "educational building" or "school" and "(Southeast Asian countries)" to search the published article in the past ten years (2010-2020). Scopus database generated 23 articles, but only 10 relevant articles were selected for this paper. While ScienceDirect generated 23 articles of the but only 8 relevant articles were selected. There were several similar articles found on both databases. Besides, the method of "reference by reference" or "snowball" was also used to find the relevant articles reviewed earlier. Google Scholar has also been used as a supporting database. In total, 27 relevant articles for this paper had been reviewed. The search string as follows; -

Science Direct	TITLE-ABS-KEY ("thermal comfort" AND "educational building" OR "school" AND "malaysia" OR "vietnam" OR "thailand" OR "singapore" OR "indonesia" OR "cambodia" OR "brunei" OR "timor leste" OR "myanmar" OR "laos" OR "philippines")
Scopus	TITLE-ABS-KEY (*"thermal comfort"* AND *"educational building"* OR *"school"* AND *"malaysia"* OR *"vietnam"* OR *"thailand"* OR *"singapore"* OR *"indonesia"* OR *"cambodia"* OR *"brunei"* OR *"timor leste"* OR *"myanmar"* OR *"laos"* OR *"*philippines*"*)
Google Scholar	Thermal comfort, educational building, classroom, Malaysia, Thailand, Singapore, Indonesia, Brunei, Philippines, Timor Leste, Laos, Cambodia, Vietnam, Myanmar.

4.0 ANALYSIS AND DISCUSSION

In the reviewed papers, these surveys were conducted in both field measurement (objective survey) and questionnaire (subjective survey) in accordance to ISO 7730 or the ASHRAE 55 standard regulations. However, there are also studies that used Computational Fluid Dynamic simulation to measure the thermal comfort level (Ge, Xu, Poh, Ooi, & Xing, 2019; Suhaila et al., 2019). The study periods vary from less than a week to a whole year with consideration of dry season and rainy season. Interrelation between objective and subjective data were shown by using statistical analysis techniques. The studied educational building was also differed in architectural (e.g. room dimensions, window wall ratio, shadings), constructional (thermal envelope properties), and mechanical (heating, cooling, and ventilation system) parameters. The studied cases are mainly air conditioned and mechanically ventilated by fans with a few cases that focused on a naturally ventilated room.

Different physical parameters were measured based on the study's purposes but similarities can be seen in almost all of the studies, measuring four environmental factors (air temperature, relative humidity, air velocity, and the radiant temperature) and two personal parameters (insulation and metabolic rate). In addition, there were also a few number of studies that measured the illumination level, concentration of carbon dioxide and noise level. However, there was also a study looking at wind direction and solar radiation in the measurement since the case study involves outdoor and semi outdoor areas (Othman, Zaki, Ahmad, & Razak, 2019).

Subjective surveys (questionnaires) mostly assessed on thermal sensations and used descriptive scales such as the seven point and five-point likert scale ASHRAE or the Bedford scales. The number of respondents in the reviewed studies differed from the smallest of 20 to the biggest of 1415 respondents with the most common age being 18 years old and above. Questionnaires were different according to age group, for instance, for primary students, the survey contained colored pictures and the questions were limited to ensure the accuracy of the data obtained.

Educational stages can be divided into three levels: 1. Primary level, (age 7–11 years old), 2. Secondary level (age 12–17 years old), and 3. University level (age 18–28 years old). Among all the thermal comfort studies carried out in the South East Asian region for the past 10 years, studies at university level were conducted the most which is 57%, primary level studies with the 36% while the secondary level was the lowest number done which is only 7%.

Almost all studies at university level were conducted in the air-conditioned room or lecture hall, where students had control on the system. This resulted in more acceptance and satisfaction of the thermal comfort. Furthermore, students at university level are not obligated to wear uniforms compared to the primary and secondary schools. However, there was also a study conducted by Amin, Akasah, & Razzaly (2015) that found out that students experienced sick building syndrome such as running nose, dry skin and flu like symptoms while using universities laboratories that have centralized air conditioning systems.

Most of the studies carried out in primary and secondary schools were done in either naturally ventilated or mechanically ventilated blocks and all students wore uniforms. Similarly, all reviewed papers on primary and secondary level reported the dissatisfaction of the thermal comfort. Almost none of the classrooms investigated fell on thermal comfort of ASHRAE- 55 standard (Kamaruzzaman & Samsul Bin Mohd Tazilan, 2013; Wong & Khoo, 2003). Study by Mao et al. (2017) in Philippines showed that the environmental conditions of their public elementary school classrooms are not conducive for learning based on the thermal, acoustical, and lighting standards. On the other hand, a study by Le, Gillott, & Rodrigues (2017) reported that children in Vietnam already adapted to the hot climate and had higher thermal comfort tolerance than adults. The study suggested that there was no need to use an air conditioning system all year round to achieve sustainability in the educational system without compromising the thermal comfort level of the students.

5.0 CONCLUSION

This study on thermal comfort in the educational building has led to the following conclusions:

- More research on thermal comfort in the educational building are needed especially in the primary and secondary level.
- Combination of field measurement and subjective measurement were used and the most common variables that are measured by researchers in their studies (air temperature, air velocity, mean radiant temperature and relative humidity).
- University students are in a better position to express their thermal sensation experiences and in a better position to make day to day adjustments because they are not regulated to wear uniforms and the activity is mostly listening to the lecture. These adjustments play a significant role in defining the thermal acceptability.
- Studies also show that thermal comfort has significant effects on students' academic performance and well-being. Still, this needs more research quantifying performance and wellbeing of students in classrooms.
- In designing new classrooms and retrofitting old classrooms, it is now required to change the priority of providing an adequate learning environment by considering the thermal comfort level.

Table 1. Summarization of thermal comfort in educational building

Years	Authors	Country	Level	TC approach	Variables	Operation Type	Time of studies	Respondent
2003	Nyuk Hien Wong, Shan Shan Khoo	Singapore	Secondary	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature Personal parameters - metabolic rate and clothing insulation	MV	21st – 24th August 2001 8am – 1pm	506 aged 13 – 18y/0, aged 26-50 y/0)
2008	Y.H. Yau	Malaysia	University	FS and SM	Environmental parameter - air velocity, room temperature and relative humidity.	AC	N/A	N/A
2009	Ibrahim Hussein, M. Hazrin A. Rahman and Tina Maria	Malaysia	Primary Secondary University	FS and SM	Environmental parameter - air velocity, room temperature and relative humidity.	AC & MV	15th December 2008 – 21st Jan 2009	141
2011	Yatim, Zain, Darus, & Ismail	Malaysia	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature	AC	N/A	232 (Age 18 – 27 y/o
2012	Makaremi, Salleh, Jaafar, & GhaffarianHoseini	Malaysia	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature Personal parameters - metabolic rate and clothing insulation	Shaded outdoor space	March & April 2010 9:00 am to 5:00 pm	200
2013	Hussin, Ismail, & Ahmad	Malaysia	University	SM	Assessment was based on the occupants' vote on the thermal sensation and impressions of comfort with regard to air temperature, relative humidity and air movement.	AC	N/A	238

Years	Authors	Country	Level	TC approach	Variables	Operation Type	Time of studies	Respondent
2013	Chan, Che-Ani, & Nik Ibrahim	Malaysia	Primary	SM	Assessment on thermal comfort satisfaction levels among teachers.	NV	N/A	413
2013	Kamaruzzaman & Samsul Bin Mohd Tazilan	Malaysia	Primary	FS	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature, noise, illuminating and carbon dioxide concentration.	NV & MV	7^{th} – 11^{th} May 2012	41
2015	Puangmalee, Hussaro, Boonyayothin, & Khedari	Thailand	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity	AC	N/A	660
2015	Amin, Akasah, & Razzaly	Malaysia	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity Subjective assessment was based on the SBS among students.	AC	November to December 2012	71
2016	Karyono & Delyuzir	Indonesia	Primary	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity	AC & NV	September & November 2014 8am and 2pm	State school : 501 (8-13 y/o) Private school: 207 (9- 13 y/o)
2016	Angeles, Ho, Le, Gillott, & Rodrigues	Vietnam	Primary	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature, noise, illuminating and carbon dioxide concentration.	NV & MV	July to September 2015.	8 – 11 y/o
2017	Mao, Chen,	Phillipines	Primary	FS and	Environmental parameter – temperature,	MV	N/A	N/A

Years	Authors	Country	Level	TC approach	Variables	Operation Type	Time of studies	Respondent
	& Sun			SM	iiluminance and sound level.			
2017	Zaki, Damiati, Rijal, Hagishima, & Abd Razak	Malaysia (Japan)	University	FS and SM	Environmental parameter - outdoor temperature, indoor air temperature, indoor globe temperature, indoor air velocity, and indoor relative humidity.	Mechanically cooling mode – AC on, Free running mode – AC off	N/A	1415 (age 20 – 23y/o)
2017	Mahyuddin, Wajdi Akashah, & Malina Jamaludin	Malaysia	University	FS and SM	Environmental parameter – relative humidity, temperature, particle matters, carbon dioxide and concentration of VOC and light intensity, outdoor environment such as wind speed, wind direction and temperature.	MV	2 weeks	20
2017	Kindangen	Indonesia	University	FS and SM	Environmental parameter - air temperature and air velocity	NV	(7am to 12pm), (12pm to 2pm), (2pm to 6pm).	182
2017	Le, Gillott, & Rodrigues	Vietnam	Primary	FS and SM	Long term recording - outdoor air temperature and relative humidity, indoor temperature and humidity Spot point measurement – temperature and relative humidity	Hybrid ventilated	March 2016 – Jan 2017	Age 8 – 11 y/o
2017	Mustapa, Salim, Ali, & Rijal	Malaysia	University	FS and SM	Environmental parameter - air temperature, globe temperature, relative humidity and air velocity	AC	Aug 2015, Dec 2015 and Jan 2016	28 (age 24-26 y/o)
2017	Samad, Aziz, & Isa	Malaysia	Primary	FS and SM	Environmental parameter - air temperature, air velocity, humidity, noise, daylighting level omitting	NV & MV	N/A	Age 10 – 11 y/o

Years	Authors	Country	Level	TC approach	Variables	Operation Type	Time of studies	Respondent
					IAQ parameters - smell and visual quality.			
2018	Hamzah, Gou, Mulyadi, & Amin	Indonesia	Primary	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature	NV	8am to 2pm	1111
2019	Karyono, Heryanto, & Faridah	Indonesia	University	FS and SM	Environmental parameter - air temperature, globe temperature, relative humidity and air velocity	AC	29 April 2013 , 11 Sept 2013, 22 May 2013	54(age 19- 24 y/o)
2019	Puangmalee, Hussaro, & Boonyayothin	Thailand	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity	AC	N/A	660(age 21 – 23y/o)
2019	Othman, Zaki, Ahmad, & Razak	Malaysia	University	FS and SM	Environmental parameter - air temperature, globe temperature, relative humidity and air velocity, wind direction, solar radiation	Outdoor and semi outdoor area	February to May 2017 9.00 am 4.00 pm	507 (age 18 – 22 y/o)
2019	Suhaila et al.	Malaysia	University	FS, SM and CFD	Environmental parameter - air temperature, relative humidity and air velocity	AC	N/A	N/A
2019	Lau, Zhang, & Tao	Singapore	University	FS and SM	Environmental parameter - air temperature, globe temperature, relative humidity and air velocity	AC, Hybrid, NV	February and April from 2015 to 2017	1043
2019	Ge, Xu, Poh, Ooi, & Xing	Singapore	N/A	CFD	CFD simulations have been carried out to evaluate the natural ventilation condition of the classrooms and identify the plausible reasons causing thermal discomfort	NV	N/A	N/A

Years	Authors	Country	Level	TC approach	Variables	Operation Type	Time of studies	Respondent
2020	Talarosha, Satwiko, & Aulia	Indonesia	Primary	Field measurement	Environmental parameter - air temperature, relative humidity, carbon dioxide concentration and air velocity	NV	N/A	N/A

**FS - field measurement, SM – subjective measurement, CFD – computer fluid dynamic simulation, AC – air conditioned, NV – Naturally ventilated, N/A – not available*

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