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THERMAL COMFORT STUDIES IN CLASSROOMS OF HIGHER EDUCATION INSTITUTIONS; A REVIEW

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ABSTRACT

There are numerous higher education institutions in the region operating in naturally ventilated buildings. It's an open fact that students spend maximum time in a day in classrooms on working days. Productivity and student's wellbeing in classrooms are attributed to thermal comfort conditions. Because of its importance, studies of thermal comfort in classrooms at various levels of education have increased in recent years. The main objective of this research is to investigate the extent of research being done on the thermal comfort studies in higher education institutes in general and in India in particular. Studies have tried assessing the thermal environments in classrooms and compared them with the available thermal comfort standards. Most of the studies proved that the student's thermal preferences are beyond the thermal comfort range specified in the standards. The study results prove a point that a greater number of thermal comfort studies at the micro level are needed to understand the thermal preferences of occupants in various contexts.

KEYWORDS: *Adaptive Thermal Comfort, Classrooms, Subjective Analysis*

INTRODUCTION

Today, Indian higher education stands amongst the largest in the world with over 799 universities, 39071 colleges, 11923 stand-alone institutions and an enrolment of 345 lakhs students (ASHE,2017). Having higher densities, classrooms with uncomfortable thermal conditions may impact the teaching-learning process negatively. Designing classrooms for better comfort conditions and efficiency, thermal comfort standards are essential. Formulation of thermal comfort standards which can supplement Indian building codes for sustainable future development of India are helped by the results of various thermal comfort researches (AK Mishra et al, 2015).

Thermal comfort is the state of mind that expresses satisfaction with the environment (ASHRAE standard 55). Physical parameters of rooms will influence thermal comfort and indoor environmental quality. In naturally ventilated buildings, the climate is dynamic and occupants tend to use various controls available to make the climate comfortable to them (de Dear R et al, 1998). It is important to note that, users of naturally ventilated buildings will have variations in thermal acceptability when compared to Air-conditioned buildings as the tolerant levels are different. (Ricardo Forgiani &others, 2015).

This shows that there is importance to the subjective feelings of the occupants in a given space. Conventionally, thermal discomfort is treated as a subjective condition while thermal sensation is an objective sensation (Hensen,1991).

It is not possible to predict universal comfort temperature for different building type having different occupancy patterns and as they are sited in different climatic contexts and used by the diverse profile of users differing in age, gender, cultural and economic backgrounds (de Dear, 1998, Kumar, 2014, Ponni, 2015). At the same time, there is no feasibility of generalized thermal comfort equation for all building types (Toe and Kubota, 2013). Occupants in naturally ventilated buildings have more relaxed expectations about the environment around and are more tolerant of temperature swings, while also preferring temperatures that tracked the outdoor climate trends (G S Brager, R J De dear, 1998).

In the recent past, there is a vast literature developed on thermal comfort studies. In addition to the research on thermal comfort studies, many literature review articles were also published on various issues of thermal comfort. In this paper, 24 research papers on field studies carried in classrooms of higher education institutions and nine papers on the literature on thermal comfort published in peer-reviewed scientific journals were reviewed to summarise various aspects of thermal comfort studies.

Review of Literature on Thermal Comfort

Thermal Comfort

Thermal comfort is one of the important characteristics of user satisfaction and energy consumption in buildings. It was also defined by Hensen as ‘‘**a state in which there are no driving impulses to correct the environment by the behavior**’’ (Hensen, 1991). A healthy indoor climate is not only important for occupant comfort & enhanced productivity, but also for minimizing building carbonfootprint. The similar definition was given by Heschong that an indoor environment which people perceive as better than “just” comfortable or where people will be pleased with the indoor environment (Heschong 1979). Thermal comfort depends on objective parameters like air temperature and speed, relative humidity, the radiant temperature of the surrounding bodies,etc. (K.N. Modeste et al., 2014) and on subjective parameters like age, sex, health, and geographical conditions,etc. As per researchers like Humphreys & Nicol climate and culture plays a major role in affecting the thermal comfort which is interlinked (Humphreys MA, Nicol, 1998). The indoor environments in naturally ventilated buildings greatly depend on the local climate, and the way environmental controls are used. Thermal comfort models described in ASHRAE 51 and CEN 15251 have been focussing on office buildings (Madhavi Indraganti, 2010). As per the Köppene Geiger system is one of the most popularly used climate classifications, climates are classified as (i) Tropical Moist Climates (A), (ii) Dry Climates (B), (iii) Moist Subtropical Mid-Latitude Climates (C), (iv) Moist Continental Mid-Latitude Climates (D) and (v) Polar Climates (E). Many surveys have been conducted in these climate types except (v) Polar climate where inhabitation is almost nil.

Thermal Comfort Models

There are two comfort models rational or heat balance model and adaptive model (Doherty TJ, Arens E, 1998). The rational model is based on the climate chamber studies and the adaptive model considers field studies of the occupants (Alison G, Kwok et al, 2010). Thermal comfort models have been researched upon since the mid-1900s, initially for military and aerospace applications, later for the assessment of climate inside vehicles and followed by the investigation of comfort parameters inside buildings (Fabbri & Kristian, 2015). Auliciem has done a number of studies for identifying

optimum temperatures for mental performance, and have done other studies on the relation between indoor temperatures with respect to various behavioral variables like posture, clothing, appearance etc. in classrooms in Europe and England (Auliciems, A.1969,1972,1975,1983&1989).

Thermal Comfort in Educational Buildings

Comfort conditions in educational buildings have always been important as the high occupant densities in classrooms can cause a negative influence on teaching-learning process and the performance of the students (Mendel M J, & Heath G A, 2005, Barrett P et al, 2015). In the 19th century the major studies in classrooms were about comfort and ventilation and in the 20th century, studies were focussed on ventilation and heating requirement in Europe and later in England (Kwok, A.G,1997). Holmberg and Wyon explained that there is no direct relation between temperatures and learning (Holmberg, I.&D. Wyon,1969). The study of thermal comfort conditions in classrooms of Cameroun shows that various airspeed preferences depend on the type of climate season, habitat structure, operative temperatures, type of interior design, materials and ventilation (KN Modeste et al.,2014). The further acceptable indoor condition cannot be achieved without an overall acceptance of air quality, acoustics, thermal and visual comfort at the same time. Any deviations from these conditions lead to discomfort and productivity will be affected in classrooms (Zahra Sadat Zomorodian et al, 2015). Though De dear and Brager stated that the 'current thermal comfort standards and models are supposed to be applicable for all type of buildings for all occupancy patterns across all types of climates', the first thermal comfort standards used worldwide were prescribed by ISO 7730(4).

REVIEW METHODOLOGY

A through literature search was carried to understand the research carried by various researchers on thermal comfort studies in education institutes in general and in higher education institutes in particular. Through this literature study, it is identified that a vast literature is available on thermal comfort studies in buildings worldwide which has increased more in the last 10-15 years. A number of research papers published in various international journals in the last 18 years is shown in Fig,1 below.

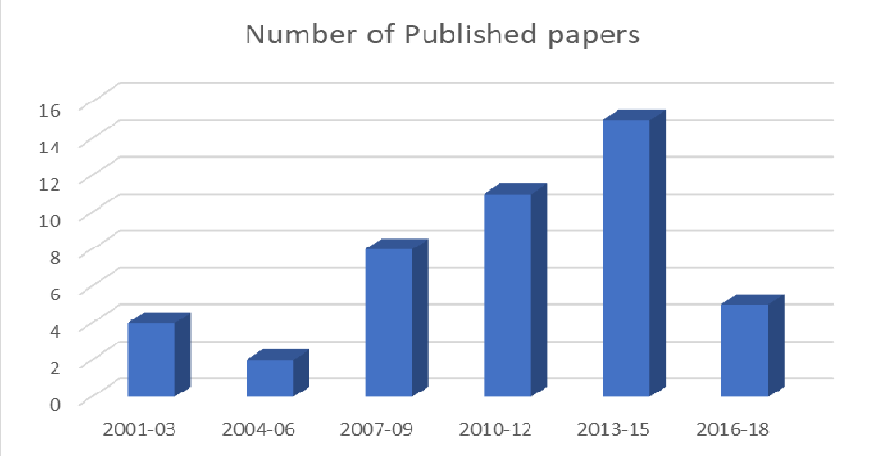

Figure 1: Number of Relevant Papers Published in Selected Journals in Last 18 Years

The following steps were carried to search the relevant papers for the literature search.

- SCI database was searched for "research papers on thermal comfort studies' published between 2000 to 2018 for the last 18 years and retrieved 38 papers from various reputed journals, conference proceedings.
- The abstracts of the papers were studied to identify the suitability of the paper and made an excel file with all the selected papers in chronological order.

Totally 38 research papers on field studies in classrooms of higher education institutions and literature review papers from various reputed international journals were shortlisted to study and understand the thermal comfort research in educational buildings. Table 1 shows the distribution of the research papers in different journals.

Table 1: Research Papers Published on Thermal Comfort in Various International Journals

Journal Title	Number of Selected papers
The Journal of Hygiene	2
ASHRAE Transactions	3
Building and Environment	16
European Journal of Scientific Research	1
Applied Ergonomics	1
Energy and Buildings	3
Applied Energy	3
Advances in Applied Science Research	1
International conference of the Architetcural Science Association	1
Building Research and Information	1
Environmental Monitoring and Assessment	1
Solar Energy	1
Sustainable Energy in Building systems	1
Building Research Information	1
Journal of mechanical Science and technology	1
International Journal of Biometeorology	1

Review Papers on Thermal Comfort Studies

There are many review papers published by many researchers on thermal comfort and on the field studies in various typologies of buildings, the first one of this was by Van Hoof J who studied the theories of thermal comfort theories by Fanger. Researchers like Yang L et al, Mishra and Ram Gopal, Ricardo Forgiarini Rupp et al and Noe¨l Djongyang studied about the available literature on thermal comfort (Yang L, et al, 2014; Noël Djongyang et al, 2010 & Haleiwa E, Hoof Java, 2012). Khoda karami and Nasrollahi, reviewed the thermal comfort studies in hospitals (Khoda karami and Nasrollahi, 2012). Zohra Sadat and others have studied thermal comfort studies done in educational buildings (Zohra Sadat Zomorodian rt al,2016). The literature studies on thermal comfort studies by researchers and the key observations are tabulated in Table 2 below.

Table 2: Summary of Reviewed Papers

S. No	Authors/Researchers	Description of the Study	Study Summery and Observations
1	Van Hoof J (2008)	Thermal comfort studies on Fanger's theory	• Fanger's heat balance model still holds good for thermal comfort studies • Thermal neutrality need not be the ideal thermal condition as people on many occasions prefer for non-neutral thermal sensations. • Very high or low PMV values need not necessarily reflect discomfort for many numbers of persons. • Applicability of the PMV model is more than the Adaptive model • By combining the individual control with the PMV model, people can create indoor environments for 100% acceptability by using Fanger's model
2	Haleiwa E, Hoof Java (2012)	Reviewed the adaptive thermal comfort studies	• There is no such thing as a set point in NV Buildings as the comfort level of the occupants is dictated by the occupants themselves • Comfort, convenience and cost are significant factors that affect people's decision on a matter related to sustainability • there are differences between the outcomes of various adaptive comfort models in use today, which needs a scientific and practice-based discussion on which approach is right • Having standards based on field studies has enormous relevance, However, the models should allow people to have a more elaborate PMV-model-like solution that reflects the real thermal sensations in naturally ventilated buildings
3	Noël Djongyang, Rene´Tchinda, Donatien Njomo (2010)	Progress of the thermal comfort studies in the last 20 years	• Both adaptive and rational approach of thermal comfort were presented • Subjects with sedentary activities in steady-state conditions, rational approach or heat balance model bring accurate predictions • An adaptive approach is better when subjects have some flexibilities in terms of behavioral and physiological adjustments, • Standards cannot be considered as an absolute reference as individuals state of mind that expresses satisfaction with the thermal environment is too diverse
4	Yang L, Yan H, Lam JC, (2014)	Thermal comfort studies with respect to energy efficiency in different parts of the World	• The PMV heat balance model works well in air-conditioned buildings but not in naturally ventilated spaces where occupants have adaptive opportunities • The adaptive approach with regression analysis tends to produce varying results (in terms of the regression coefficients

			and predicted comfort temperature ranges) from different field studies. • More efforts are required to reconcile and unify the different adaptive models with a wider range of comfort temperature, which could have significant energy savings in both air-conditioned and naturally ventilated buildings. • Cooling requirements in an indoor environment can be reduced with a wider range of indoor thermal environment
5	Mishra and Ram Gopal (2013)	thermal comfort studies according to climatic zones	• Changing climate, pollution, and fossil fuel depletion, natural ventilation would become a norm with the right standards and design interventions. • All other climates except type 'A' have broader neutral temperatures • Buildings can determine adaptive behavior as per the design and function • Occupants try to use all adaptive options to restore comfort • People will opt for gadgets like AC's if given a chance • Adaptive options like opening windows are very common in all studies, other options depend on other parameters like climate and culture, etc.
6	Ricardo Forgiarini Rupp, Natalia Giraldo Vásquez, Roberto Lamberts (2015)	Reviewed research papers published in last 20years on issues of thermal comfort studies in buildings	• Research in thermal comfort studies have increased and many adaptive thermal comfort models and to adjust PMV/PPD model have emerged in different conditioning modes • Thermal comfort cannot be explained by six parameters only in many situations and factors that influence the occupant's thermal sensation like culture, behavior, age, gender, individual preferences, control over the environment, thermal history and space layout needs to be studied • Thermal comfort is a complex topic and we are far from understanding all its interrelated aspects, needed a better understanding of thermal comfort to face climate change and energy demand • Further studies in this domain will deepen the knowledge base for better understanding of the topic
7	Khoda karami and Nasrollahi (2012)	Reviewed the thermal comfort studies in hospitals	• Studies were not done to reconcile the different thermal comfort requirements of different types of occupants who compulsorily must stay in one room in hospitals • In hospitals, important areas focussing on thermal comfort for staff and its relation with their productivity, using the different heating system to prevent

			hypothermia in the patient and to improve the thermal comfort for hospital staff simultaneously needs to be undertaken
8	Zahra Sadat Zomorodian, Mohammad Tahsildoost, Mohammadreza Hafezi (2016)	Reviewed literature on thermal comfort studies in class-rooms in educational buildings (primary, secondary and higher)	• The importance of thermal comfort study is related to the relationship between occupant's satisfaction, the functioning of space and energy consumption • As students spend much of their time in schools, it is important to provide a good thermal environment and indoor air quality. • Thermal discomfort may cause unsatisfactory conditions both for students and teachers • Existing thermal comfort standards like ASHRAE 55, EN15251, and ISO7730, etc. are inappropriate for assessing classroom thermal environments. • Thermal comfort studies shall be done for the whole year with more subjects for more generalized results. • Developing spatial and temporal thermal comfort metrices can be useful classrooms design evaluation

Table 3: Summary of Reviewed Papers

Thermal Comfort studies in University Classrooms														
S.No	Year	Country	Climate	Ventilation Type	Season	Sample Size	Comfort Band (Limits)			Thermal Comfort Model	Model Compatibility		Author/s	Journal/Conference
							Limit	Neutral	Higher		ATC	RTC		
1	2002	Japan	C	AC	Whole Year	40	-	25.5	-	Rational	-	Underestimated	Ishii J	16th international congress of biometeorology
2	2006	Italy	C	NV	Mid-Season & Winter	959	20.24	-	23.56	Rational	-	Compatible	Buratti C, Ricciardi P	Conference' Research in Building Physics and Building Engineering'
3	2006	China	C	NV	Winter & Autumn	186	18.4	22	26.1	Rational	-	-	Hu PF, Liu W, Jiang ZN	International Journal of Architectural Science
4	2007	China	C	NV	Spring	1273	-	21.5	-	Rational	-	Overestimated	Zhang G, Zhenga C, Yanga W, Zhanga Q, Moschandreasa DJ.	Building and Environment
5	2008	Nigeria	A	NV	Summer	200	24.88	26.58	27.66	Rational & Adaptive	Lower	Overestimated	Ogbonna AC, Harris DJ	Applied Energy
6	2009	China	C	NV	Whole Year	3621	16	22.8	30	Rational	-	Underestimated	Yao R, Li B, Liu J.	Building and Environment
7	2010	China	C	NV	Whole Year	3621	16	22.8	30	Rational & Adaptive	Higher	Overestimated	Yao R, Liu J, Li B	Applied Energy
8	2010	Pakistan	B	AC	Summer	500	22.4	25.23	26.6	Rational & Adaptive	Compatible	-	Chirarattananon S, Htan NN, Menon RA, Vangtook P	
9	2010	Thailand	A	NV	Summer	206	-	28	-	Rational & Adaptive	Compatible	-	Chirarattananon S, Htan NN, Menon RA, Vangtook P	
10	2011	China	D	AC	Winter & Summer	205	-	20.7/26.8	-	Rational	-	Underestimated	Cao B, Zhu Y, Ouyang Q, Zhou X, Huang L	Energy and Buildings
11	2011	Korea	C	NV	Mid-Season	205	17	-	25	Rational	Higher	Underestimated	Jung GJ, Song SK, Ahn YC, Oh GS, Im YB	Journal of mechanical Science and technology
12	2012	Portugal	C	NV	Whole Year	732	-	-	-	Rational & Adaptive	-	Compatible	Carvalho PMd, Silva MGd, Ramos JE	Building and Environment
13	2014	China	D	NV	Mid-Season & Winter	200	-	22.7/21.7	-	Rational	-	-	Wang Z, Li A, Ren J, He Y	Energy and Buildings
14	2015	Italy	C	NV	Spring	126	18.6	21.8	24.5	Rational & Adaptive	Compatible	Compatible	Nico MA, Liuzzi S, Stefanizzi P.	Applied Ergonomics
15	2014	China	C	NV	Winter	640		20.9		Rational & Adaptive	Compatible	Underestimated	Tao Q, Li Z	Proceedings of 8th Int symposium on HVAC
16	2014	China	D	NV	Whole Year	66	21.7	24.2	26.6	Rational & Adaptive	Higher	Overestimated	Li M, Cao B, Zhu Y	Proceedings of 8th Windsor Conference
17	2014	India	C	NV	Mid-Season & Winter	228	22/23.5	-	23.5/30.7	Rational & Adaptive	-	-	Baruah P, Singh MK, Mahapatra S	30th International PLEA Conference
18	2015	India	A	NV	Whole Year	67	22.1	29	31.5	Adaptive	Compatible	-	Mishra AK, Ramgopal M.	Building and Environment
19	2014	India	A	NV	Mid-winter-Mid summer	338	0			Adaptive			Mishra AK, Ramgopal M.	Building and Environment
20	2014	India	A	NV						Adaptive			Mishra AK, Ramgopal M.	Conference' proceedings
21	2017	Netherlands	C	AC	Summer					Rational &Adaptive			AK Mishra,MRH Derks,L.Kooi, MGLC Loomans,HSM Kort	Building and Environment
22	2018	India	B	NV	Summer					Adaptive			Sanjay Kumar, Manoj Kumar Singh, Anuj Mathur, Jyotirmay Mathur, Sanjay Mathu	Building and Environment
23	2018	India	B	NV	Summer					Adaptive			Manoj Kumar Singha,Sanjay Kumarb, Ryozo Ookaa, Hom B. Rijale, Gyanesh Guptad, Anuj Kuma	Building and Environment
24	2018	India	C	NV	Monsoon and Winter					Adaptive			Aradhana Jindal	Building and Environment

Field Study Methodology

All the research studies carried on thermal comfort field studies were done in two stages, one is about the objective survey and the second on subjective analysis as per the standard regulations prescribed in ASHRAE 55 for conducting these surveys. Most of the surveys carried in these papers were done as per ISO 7730 standards or ASHRAE 55. To understand the inter-relation between these two surveys, linear regression methods were used.

Objective Study: Different physical parameters like air velocity, air temperature, relative humidity, and radiant air temperature, etc. were measured in the studied classrooms. Building measurements and material specifications were also detailed out. The study procedures were carried as per Class I Class II &Class III protocols for field measurements. Studies have also measured human parameters like metabolic rate and clothing level which are used to calculate Predicted Mean Vote (PMV), Effective Temperature (ET) and operative Temperature (Top) in a central location in the room at sitting height. Studied buildings are either from all types of ventilating systems including Air conditioned, Mechanical and naturally ventilated buildings. In some cases, illumination levels were also recorded.

Subjective Surveys: For thermal comfort studies, subjective surveys are very important to understand the individual's perception about indoor comfort. There are no standard procedures to define how many subjects have to be surveyed or for the duration of the surveys, (Mishra and Ram Gopal, 2013). This is evident in the studies carried by researchers with the number of respondents is varying from 28 in one study to 4000 in some other studies. Different questionnaire types were used to get the required information from the respondents as per the age group. All the analysis and study reviews were carried as per the standards prescribed in ASHRAE 55and ISO 7730.

Discussion on Thermal Comfort Studies in Universities

Many studies have been carried in naturally ventilated University buildings in China (S. No 3,4,6,7,10,13,15,16), Japan (S.No.1), India (17-20&22-24). Research about thermal comfort studies in the building have started around 1970's but picked up the momentum in the last 20 years only. The identified 24 research papers are tabulated in Table 1. As per the International standards, thermal comfort is a situation in which an individual feels neither too hot nor too cold in a given environment with adequate air movement and comfortable lighting. Thermal comfort also depends on subjective parameters like age, sex, health, and geographical conditions, etc. And also depends on objective parameters like air temperature and speed, relative humidity, the radiant temperature of the surrounding bodies, etc. (K.N. Modeste et al., 2014). For maximizing the learning and productivity which are important for schools and offices, thermal comfort becomes more relevant and important. Fanger's models can represent well about the occupant responses in office buildings whereas in schools, adaptive mechanisms may influence the occupant thermal comfort significantly (Maria Anna Nico et al,2015). Humphreys (1981) and Nicol (1974, 1995, 1996) have done many studies to show that people are not the passive recipients of thermal environments but exhibit various behavioral adjustments to restore comfort. It is widely known that comfort in a space is also influenced by other environmental factors than just thermal comfort (Lada Hensen Centnerová et al.,2010). Many researchers have carried studies on thermal comfort in naturally ventilated buildings of tropical climates like Singapore (de Dear, 1990, Wong et al., 2002), Malaysia (Zainazlan et al, 2007) and in China (Xiaojiang et al., 2006). After extensive studies and occupant's subjective evaluation, adaptive thermal comfort standards for the hot and humid climate were proposed by Nicole (Nicole, 2004).

Through literature study it is evident that there has been a lot of research happening worldwide to determine thermal comfort standards in different environments, there is not much research happened to understand thermal comfort standards for naturally ventilated buildings particularly in the Indian context. In Indian context researchers like Sharma and Ali (1986) in office buildings and Anupama et al (2007), Indraganti (2010) and Manoj et al (2010) researched and evaluated the occupant's subjective thermal responses in residential buildings of composite and cold climatic zones. Zhao Jun et al, 2016 conducted a survey to analyse occupant's adaptation in university classrooms and dormitories in Harbin

during Oct 13 to April 2014 and shown that the acceptable temperature limits were lower in classrooms than in dormitories, due to difference in adjustment habits and thermal sensation votes have shown that students felt classrooms were hotter than dormitories which were on neutral side. S**tefano Paolo Corgnati** et al,2009 have done a similar study in naturally ventilated Italian classrooms during mid seasons and identified that occupants were preferring a slightly warm environment in the winter period. This proves an interesting hypothesis of thermal preference trend which is contrary to the previous researches conducted in the classrooms of Italian university and high school during the heating season. **Runming Yao** et al,2010 did a study to examine the thermal perceptions and adaptive responses of occupants 'in naturally conditioned university classrooms in Chongqing, China. This study state that occupants are less thermally sensitive in the naturally conditioned buildings than in an air-conditioned building and can tolerate a broader variation of air temperature under the AMV model than that under the PMV model. **Plabita Baruah** et al,2014 have done a study in NV classrooms during Summer and winter seasons to evaluate thermal comfort in naturally ventilated buildings in India and the results reveal that the subjects did not feel extreme levels of thermal discomfort during these periods. The acceptable limit of comfort temperature recommended by ASHRAE is closely similar to the survey results for winter months and is different for the summer months. It also deliberates that the classrooms thermal environment requirement is completely different from that of the residential and office environment, so it demands a separate thermal environment assessment study to be carried out.

Inferences from the Review

- Researches done in various similar contexts prove that occupants are comfortable in temperature range starting from 20.7 ^{0}C to 29^0 C in various climatic zones.
- Thermal environment of school classrooms affects students' performance (Zeiler W et al, 2009 & Wargocki P et al, 2013). But there were not may researchers about the influence of thermal comfort on performance in University classrooms.
- Most of the researches could not identify if there is any relation between the thermal perception of occupants with respect to Architectural parameters like building geometry, material specifications, orientation, etc. A detailed study about the influence of building properties w.r.t thermal preference is necessary.
- Studies were conducted in various university classrooms shows that the results of these studies are not in tune with thermal comfort standards prescribed by ISO 7730(2005), ASHRAE 55 (2004) based on rational comfort approach or ASHRAE 55 (2010) based on adaptive comfort approach. It proves that there are wide disparities in the way people perceive comfort conditions in various places.
- In the comfort studies carried in university classrooms, more than 60% of the studies were carried in a limited time period. Since many regions which fall in a hot humid climate in India consists of non-comfortable conditions in more than one season, it is important to conduct a survey for more than one season to understand the perceptions better.

- Through this literature review, it is found out that researches have not been done keeping in view of the architectural properties of the spaces and thermal properties of the building materials while studying the perceptions of the occupants. This aspect can be explored to draw a relation between the architectural or thermal properties of the buildings with the perceptions of the occupants in various climatic conditions.

CONCLUSIONS

Students spend most of their time in classrooms and comfortable thermal environment shall be provided for creating a better learning experience. Studies have proven that the quality of thermal environment will impact the productivity of the students. Same time employing the energy-intensive artificial conditioning systems will have an adverse impact like increasing carbon footprint besides increasing the energy consumption levels. Researches prove that comfort temperature band is not common across various climate zones and there is a wide range of neutral temperatures preferred in the same climate zones. Most of the studies carried in a particular season or month with a limited number of respondents due to practical issues of conducting surveys during working hours. It is suggested to carry yearlong study with a greater number of participation from the respondents may be better for generalizing the results. Not many studies were carried to understand the influence of occupants economic or cultural backgrounds on their comfort preference. The thermal feeling is an individual perception and as per the point No.4 of the discussions above, if the thermal comfort standards cannot be generalized for the entire population instead shall develop based on the differences in climate/regional/age/activity etc. For this to happen more studies needed to be carried in each specific climate and populations with differences in economics, cultural and based on different ages to understand the variations in thermal preference as per their economic and cultural background.

REFERENCES

1. *Alison G, Kwok, "Thermal Comfort in Naturally-Ventilated and Air-Conditioned Classrooms in the Tropics", PhD thesis, University of California, 1997*
2. *Alison G, Kwok, Nicholas B, Rajkovich, "Addressing climate change in comfort standards", Building and Environment 2010; 45:18–22.*
3. *Auliciem A., "Warmth and comfort in the subtropical winter: a study in Brisbane schools," J Hyg 1975;74(3):339–43.*
4. *Auliciem A, "Effects of weather on indoor thermal comfort," Int J Biometeorol 1969;13(2):147–62.*
5. *Auliciems A, "Thermal requirements of secondary school children in winter," J Hyg 1969;67(01):59–65.*
6. *Auliciems A, "The atmospheric environment a study of comfort and performance," Toronto: Department of Geography University of Toronto Press; 1972.*
7. *AHRAE, Standard 55, "Thermal environmental conditions for human occupancy", 2013*
8. *Barrett P, Davies F, ZhangY, BarrettL, "The impact of classroom design on pupils' learning: final results of a holistic, multi-level analysis," Build Environ 2015;89: 118–33*

9. *Baruah P, Singh MK, Mahapatra S, "Thermal comfort in naturally ventilated classrooms, in 30th international plea conference," Ahmedabad: CEPT University; 2014*
10. *BRE Publication Draft PD117/76. Garston, Building Research Establishment; 1976.*
11. *Buratti C, Ricciardi P, "Adaptive analysis of thermal comfort in university classrooms: Correlation between experimental data and mathematical models," Build and Environment, 2009;44(4):674–87.*
12. *Cao B, Zhu Y, Ouyang Q, Zhou X, Huang L, "Field study of human thermal comfort and thermal adaptability during the summer and winter in Beijing," Energy and Buildings, 2011;43(5):1051–6*
13. *Carvalho PMd, Silva MGd, Ramos JE., "Influence of weather and indoor climate on clothing of occupants in naturally ventilated school buildings", Build and Environment, 2012:1–9*
14. *Chirarattananon S, Htan NN, Menon RA, Vangtook P, "Thermal comfort assessment in two tropical regions and radiant cooling as a passive cooling option", 2010.*
15. *Corgnati SP, Ansaldi R, Filippi M., "Thermal comfort in Italian classrooms under free running conditions during mid seasons: assessment through objective and subjective approaches", Build and Environment, 2009;44(4):785–92.*
16. *de Dear R, Brager G., "Developing an adaptive model of thermal comfort and preference", ASHRAE Trans 1998;104(1):145-167*
17. *de Ddear RJ, Akimoto T, Arens EA, Brager G, Candido C, Cheong KWD, LiB, Nishihara N, Sekhar SC, Tanabe S, Toftum J, Zhang H, ZhuY., "Progress in thermal comfort research over the last twenty years', Indoor Air 2013.*
18. *Djongyang N, Tchinda R, Njomo D, "Thermal comfort: a review paper. Renewable Sustainable Energy Review', 2010;14(9):2626–40.*
19. *E. Rajasekar and A. Ramachandraiah, "Adaptive comfort and thermal expectations – a subjective evaluation in hot humid climate", Proceedings of Conference: Adapting to Change: New Thinking on Comfort Cumberland Lodge, Windsor, UK, 9-11 April 2010. London.*
20. *Fabbri & Kristian, "A Brief History of Thermal Comfort: From Effective Temperature to Adaptive Thermal Comfort", Indoor Thermal Comfort Perception (pp. 7-23). New York, Springer.*
21. *Guoqiang Zhang &others, 'Thermal Comfort investigation of Naturally Ventilated Classrooms in a Subtropical region", Indoor and Built Environment, April 2007*
22. *Halawaa E, Hoof Jv., "The adaptive approach to thermal comfort: a critical overview", Energy and Buildings, 2012; 51: 101–10.*
23. *Holmberg, I. and D. Wyon. "The dependence of performance in school on classroom temperature," Educational and Psychological Research, 1969(31): 120.*
24. *Humphreys MA, Nicol JF., "Understanding the adaptive approach to thermal comfort", ASHRAE Trans 1998;104(1): 991-1004*

25. *Hu PF, Liu W, Jiang ZN., "Study on indoor thermal sensation of young college students in the area which is hot in summer and cold in winter", Int. Journal of Architecture Science 2006;7(2):47–52*
26. *Indraganti, M., "Adaptive use of natural ventilation for thermal comfort in Indian apartments", Building and Environment,2010 (45)1490-1507*
27. *Jung GJ, Song SK, Ahn YC, Oh GS, Im YB., "Experimental research on thermal comfort in the university classroom of regular semesters in Korea", Journal of Mechanical Science and Technology, 2011;25(2):503–12*
28. *Khodakarami J, Nasrollahi N., "Thermal comfort in hospitals – A literature review", Renewable Sustainable Energy Review, 2012;16(6):4071–7*
29. *Lada Hensen Centnerová & Atze Boerstra, "Comfort is more than just thermal comfort, Adapting to Change: New Thinking on Comfort", Proceedings of Conference, Cumberland Lodge, Windsor, UK, 9-11 April 2010, London*
30. *Li M, Cao B, Zhu Y, "Indoor thermal comfort Survey in campus buildings in Beijing for a long time, in Counting the cost of comfort in a changing world", London, UK; 2014*
31. *Mishra AK, Ramgopal M., "Field studies on human thermal comfort-An overview", Building and Environment, 2013.*
32. *Mishra AK, Ram Gopal M., "A thermal comfort field study of naturally ventilated classrooms in Kharagpur, India", Build and Environment, 2015;92: 396–406.*
33. *Mishra AK, Ram Gopal M., "A comparison of student performance between Conditioned and naturally ventilated classrooms", Build and Environment, 2015; 84:181–8.*
34. *Maria Anna Nico, Stefania Liuzzi &Pietro stefanizzi, "Evaluation of thermal comfort in university class rooms through objective survey and subjective preference analysis", Applied Ergonomics 48(2015),111-120*
35. *Mendell M J, Heath G A., "Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature", Indoor Air 2005; 15(1):27–52.*
36. *Modeste KN, Tchinda R, Ricciardi P., "Thermal comfort and air movement preference in some classrooms in Cameroun", Revue des Energies Renou-velables 2014;17(2):263–78*
37. *Nicol F, "Adaptive Thermal Comfort Standards in The Hot–Humid Tropics. Energy and Buildings", 628–637. Merabti Ahmed et al.,The Influence of Porosity on Thermal Comfort in an Isolated Habitat of the Roof by a Porous Medium,IMPACT : International Journal of Research in Engineering & Technology(IMPACT :IJRET), Volume 5, Issue 7, July 2017, Pp 65-70.*
38. *Nico MA, Liuzzi S, Stefanizzi P, "Evaluation of thermal comfort in university classrooms through objective approach and subjective preference analysis", Applied Ergonomics, 2015;48: 111–20*
39. *Ogbonna AC, Harris DJ., "Thermal comfort in sub-Saharan Africa: field study report in Jos-Nigeria", Applied Energy, 2008;85(1):1–11.*

40. *Plabita Baruah, Manoj Kumar Singh, & Sadhana Mahapatra, "Thermal Comfort in Naturally Ventilated Classrooms", 30th INTERNATIONAL PLEA CONFERENCE 16-18 December 2014, CEPT University, Ahmedabad*
41. *Pepler RD., "The thermal comfort of students in climate controlled and non-climate-controlled schools", ASHRAE Transactions, 1972;78(1):97–109*
42. *Runming Yao, Jing Liu, Baizhan Li, "Occupants Adaptive responses and perception of thermal environment in Naturally conditioned University class rooms", Applied Energy 87 (2010) 1015–102*
43. *Ricardo Forgiarini &Others, "A Review of human thermal comfort in the Built Environment", Energy and Buildings, 2015*
44. *Rupp RF, Vásquez NG, Lamberts R., "A review of human thermal comfort in the built environment", Energy and Buildings, 2015; 105:178–205*
45. *Stefano Paolo Corgnati, Roberta Ansaldi, Marco Filippi, "Thermal comfort in Italian classrooms under free running conditions during mid seasons: Assessment through objective and subjective approaches", Building and Environment,2009, 44,785–792*
46. *Tao Q, Li Z, "Field study and adaptive equation of thermal comfort in university classrooms in the subtropics in winter", 2014, vol. 261, 121–9, Proceedings of 8th Int symposium on HVAC*
47. *Van Hoof J., "Forty years of Fanger's model of thermal comfort: comfort for all",2008, Indoor Air, 18(3):182–201*
48. *Wargocki P, Wyon DP. "Providing better thermal and air quality conditions in school classrooms would be cost-effective", Build and Environment, 2013;59: 581–9.*
49. *Yang L, Yan H, Lam JC., "Thermal comfort and building energy consumption implications – A review", Applied Energy,2014; 115:164–73.*
50. *Yao R, Li B, Liu J., "A theoretical adaptive model of thermal comfort – Adaptive Predicted Mean Vote (PMV)", Build and Environment, 2009;44(10):2089–96.*
51. *Yao R, Liu J, Li B., "Occupants' adaptive responses and perception of thermal environment in naturally conditioned university classrooms", Applied Energy 2010;87(3):1015–22.*
52. *Zahra Sadat Zomorodian, Mohammad Tahsildoost, Mohammad rezaHafezi., "Thermal comfort in educational buildings: A review article", Renewable and Sustainable Energy Reviews,2016*
53. *Zeiler W, Boxem G., "Effects of thermal activated building systems in schools on thermal comfort in winter", Build and Environment, 2009;44: 2308–17.*
54. *Zhaojun Wanga*, Xuexiang Zhanga, Haoran Ninga, Yuchen Ji, "Human Thermal Adaptation in University Classrooms and Dormitories in Chinese Severe Cold Area in Winter", Procedia Engineering 146 (2016) 24 – 31*