School Environment and Students' Comfort A Review Paper

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This paper is the author's partial work of PhD dissertation

***Abstract*—**Life standards are improving and environmental comfort is considered as a necessary component of workplace contentment and production. Schools are one of the most common types of organizations and students spend almost one-third of their lives in school buildings. Thus, school environment including gradually developing technology plays a significant role in their wellbeing and outcome. For instance, despite all its benefits, technological developments have brought some psychological and physical concerns into school environment such as noise pollution and high levels of carbon monoxide emission. Taking into consideration that hundreds of millions of students are registered into schools from pre-primary to university world-wide every year, school environment concept and its components – basically thermal, indoor air quality, visual and acoustic comfort – have to be dealt meticulously. While doing so, new actors such as technological developments and environmental changes should be also taken into account since school environment is a changing/developing concept.

***Keywords*—**Environment, school, students' performance, students' comfort

I. Introduction

School buildings are learning/teaching environment and they have influence on students' wellbeing as well as performance. Schools are supposed to provide environment where students feel that they are comfortable and safe in all manners. They are also supposed to provide surroundings for students to be resourceful, sociable, productive and able to share knowledge. Bernardi & Kowaltowski [1] state that adverse environmental conditions in schools such as high levels of noise, inappropriate temperatures, poor lighting and insufficient equipment negatively affect students' performance and can lead to some health problems. Thermal, visual, acoustic and indoor air qualities are main determiners for indoor environment quality and comfort. For instance, most naturally ventilated schools can get very hot during the summer times, poorly ventilated classrooms can even cause some illnesses to develop and spread, classroom design and coloring may cause poor visual perception, badly-balanced and malfunctioning appliances can increase environmental noise that lower students' attention and. However, other factors such as school design, school environment education and awareness, school energy policy, financial issues, climate conditions and living standards of students and the region can also play important roles on students' comfort and performance in schools. For instance, Pinder et al. [2] claim that organizations that focus on environmental issues are more inclined to cultivate more effective working environment and such organizations consider their staff's needs as top priority. It should be kept in mind that Sick Building Syndrome (SBS) is one of the major reasons for stress, work place related illnesses and productivity loss [3].

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II. Energy Consumption and Students' comfort

Energy consumption in schools keep increasing due to some factors such as the use of more technological equipment, ventilation systems owing to the global warming, more opportunities for education and raise in life standards. Research results, for instance in Luxembourg [4] and in Scotland [5] support the notion. Consequently, energy consumption has become an issue of students' comfort and outcome, and attract more scientists and academicians for research. As Lourenço et al [6] state, the relation between energy consumption and students' comfort also changes "energy consumption patterns". However, some researches show that even high energy consuming schools do not provide environmental comfort for students. For instance, in Slovenia 60% of students complained about the poor indoor air quality in their schools with the highest energy consumption [7].

III. Thermal comfort

Roelofsen [8] urges that thermal comfort along with indoor air quality is highlighted as the most substantial component that affects productivity. He also states that thermal environment plays a crucial role on how people experience air quality. Thermal balance of human body is achieved when the human body heat is in balance with the environmental heat to allow human body heat to dispel. Individual factors such as body heat exchange, dressing and personal metabolic / mental state and environmental factors such as surrounding temperature, ventilation rate, unfavorably cold and hot window and wall surfaces, humidity and mean radiant temperature on walls and other surfaces [9] can play a role on a person's thermal comfort. Studies on occupants' thermal comfort show that people in a thermally comfortable environment are more productive [10] and healthier [11].

ANSI/ASHRAE Standard 55 describes thermal comfort as "the condition of mind that expresses satisfaction with the

thermal environment and is assessed by subjective evaluation" [12] making thermal comfort the key objective in school building design [13]. Kamarruzzaman and Tazila [9] consider thermal comfort as "a key component of quality of indoor environments and environmental elements such as heat from electrical lighting, lack of adequate ventilation, high humidity levels, and poorly performing building envelopes can contribute to poor thermal comfort".

According to the ASHRAE 55 Standard [12] an average person at rest with a 1.8 m² body surface area produces 1.71 Btu per hour and this average is called as '1 met'. A human's metabolic rate can change between 0.7 and 2.0 (or above) met depending on the activity (s)he is involved. Along with 'met' as person's thermal state, eating habits and body shape can also influence an individual's metabolic rate and consequently thermal comfort [14]. Furthermore, unfavorably low (< 20-30%) and high (> 60%) relative humidity can cause discomfort by affecting skin evaporation [15].

Students spend 1/3 of their lives in schools and environmental conditions can affect their outcome more than adults in offices as they are more vulnerable to hostile environment. However, there are fewer studies on the environmental effects on students' comfort and success than adults at work [16]. Yet, it can be derived from relevant literature that extreme conditions of temperature and humidity reduce students' attention span [17] and their work speed, and manual skills decrease in colder temperatures rather than warmer ones [18]. Increasing the number of electrical ventilation systems open a new area of research on the effects of new systems and mixed ventilation applications, along with the new school building designs. Unfortunately, thermal comfort in numerous naturally ventilated schools are below the ASHRAE standards [19] and naturally ventilated buildings are usually colder in winters and warmer in summers than the buildings with HVAC systems [20]. Elbayoumi et al. [21] state that "the seasonal fluctuation of ambient temperature and relative humidity and as a result the ventilation rate can lead to sick building syndrome (SBS) and reduce students' acuity and output".

The two thermal comfort models, the adaptive model which can be more suitable for naturally ventilated buildings and the Predicted Mean Vote (PMV) which can be more appropriate for the building under thermal control, are often used for thermal comfort of buildings. PMV is constructed on four environmental variables as air temperature, air rate, moisture in the air and mean radiant temperature along with two individual variables as metabolic rate and dress insulation. It takes the (indoor environment) predicted Percentage of People Dissatisfied (PPD) into account to calculate the mean comfort vote of occupants. The adaptive model places a key role on an individual's adaptive behavior such as activity, clothing and position, and outdoor temperature [11]. PMV index establishes a seven-level temperature scale as -3 cold, -2 cool, -1 slightly cool, 0 neutral, 1 slightly warm, 2 warm and 3 hot. According to the PMV and PPD indexes, an individual's thermal balance/comfort is achieved "when the body heat loss is equal to the body metabolic heat (PMV=0)" [22]. The adaptive model, the indoor comfort temperature is correlated with regional climate and individuals in various regions can feel comfortable with different temperatures [23].

When it comes to the standards, CBE Thermal Comfort Tool for ANSI/ASHRAE Standard 55, European thermal comfort standards EN 15251, ISO 7730 and Predicted Percentage Dissatisfied (PPD) directories can be used for thermal comfort analysis and calculations [24]. It is also worth mentioning that in tropic zones such as Malaysia building occupants can adapt to higher temperatures that are beyond the ASHRAE comfort zone [25].

IV. INDOOR AIR QUALITY

The hostile consequences of poor indoor air quality (IAQ) on people's health let alone children's is obvious. Roelofsen [8] states that indoor air quality is one of the most substantial component that affects productivity, while Wood argues that even little development in indoor air quality will directly increase efficiency. Studies on IAQ and students' comfort indicates that IAQ in numerous countries are below the satisfying levels and they are the primary reason for several illnesses such as communicable ailments and sick building syndrome (SBS) along with increasing number of students [26]. Additionally, poor ventilation is the cause of up to 20% of absenteeism [27] and poorer students' performance [28].

Children spend great amount of time at schools and they are exposed to different sources of pollution from furnishings [29] to carbon monoxide [30]. As indoor air pollutants can come both from inside and outside, the source of pollutants should be observed well and a proper HVAC system should be installed. Pollutants can vary according to time, season, location and societal issues and can include tiny particles such as fibers, dust, mold, bacteria, unfavorable gas molecules etc. As classroom ventilation rates are poorer than the given standards and children's metabolisms are more sensitive, they are more likely to suffer from long term consequences. Taking into consideration that increasing number of artificial ventilation systems are needed to be used in classrooms due to global warming, the issue is becoming more crucial. On the other hand, high quality of indoor air and outdoor air supply rates with more than 25lt each second increase students' accuracy and speed [31].

The American Society of Heating, Refrigeration and Air Conditioning Engineers Standard 62.1 [32] in U.S. and EN13779 [33] and EN15251 [34] in European Union provide standards of favorable IAQ. According to the ASHRAE Standard 55-1992, comfortable indoor temperature must be between 20°C and 25.5°C, humidity between 30% to 60% depending on the season, air ventilation in a range of 15 to 60 cubic feet per minute of outdoor air for each person in the area served by the HVAC system and finally CO2 levels less than 700 parts per million (ppm) above ground levels [35].

EN15251 categorizes IAQ into low, moderate, medium and high quality matching to values 1200 ppm, 800 ppm, 500 ppm and 250 ppm respectively [36]. It is understandable that these rates also depend on the number of occupants, room size, activity and metabolic rate [37]. Despite no specification for

humidity in BB101, the UK building regulations state that the RH should not surpass 70% for longer than two hours, and/or 90% for longer than one hour in a 12-hour-period throughout the warming season [38].

A lot of studies show that classroom air qualities are poorer than expected. For instance, Godwin and Batterman's research [39] show that only 27% of classrooms have sufficient ventilation rate and Hellwig's research [40] indicates that 47% of classrooms in the summer time and 89% of them in the winter time exceed 1500 ppm CO2 concentration. Most of these classrooms were naturally ventilated (mostly by opening windows) and it shows that natural ventilation is not good enough for high indoor air quality, although the U.K. Government recommends natural ventilation where possible to lessen environmental impact and costs [41].

To prevent the adverse consequences of low quality indoor air ventilation rates, temperatures, air humidity and CO2 concentrations should be adjusted according to international standards. Thus, the first step to solve the IAQ problem is to obtain necessary air quality data. Having collected sufficient data, the problem can be solved to some extend with proper HVAC systems. For instance, Jonesa and Kirbyb [36] suggest top-down wind-driven natural ventilation system which was installed in more than 1100 schools in U.K. and it improved the IAQ considerably.

Some other practical measurements can be counted as follows;

- Regular maintenance precautions
- Source Control: not to bring needless pollutant to school
- Eliminating pollutants before they are absorbed into school indoor environment, specifically air
- Regulating duration, amount and pollutant site
- Educating students on pollutants and classroom safety

V. VISUAL COMFORT

There are adequate number of researches and evidence that lighting in classroom has effects on teachers and students. Preferences between natural daylight or artificial lighting for better control on lighting is debatable. While Lyons [42] states that full spectrum fluorescent lighting can enhance learning, Rittner and Robbin [43] found that daylight improves learning and retainment. Xue FJ. [44] states that day-lighting improves students' performance and productivity, and enhance indoor environmental quality. Additionally, day-lighting reduces general energy consumption of a building. For instance, environmental shading from neighboring buildings can affect a building's yearly energy consumption up to 25–28 kWh/m2 [45]. These values may play an important role in total energy demand and energy peaks.

It is understandable that a well-balanced integration of day light and artificial one is the key as preferable levels of daylight is not always available. Recently growing interest in energy consumption is incorporating daylighting and electricity-based lighting to lessen energy consumption [46]. It should also be kept in mind that better solutions can be found in the future throughout technological and medical improvements. So far, The Chartered Institution of Building Services Engineers CIBSE [47] and DfEE [48] can be applied for the best practice.

The correlation between lighting and children's / students' behavior and success may throw lights on sustainable educational success. According to Schreiber's findings [49], low illumination increases students' interest and they become calmer. Similarly, indirect diffuse of full spectrum fluorescent lamps reduces children's maladaptive behavior [50].

In comparison with fluorescent lighting, incandescent lamps have an advantage that as cooling of wires takes longer frequency modulation in incandescent lamps the modulation does not change as fast as in fluorescent lighting. While the standard AC supplies in Europa work with 50 Hz of frequency, this frequency in fluorescent lightings can reach 100 Hz [47]. Although it is unnoticeable, 100 Hz flickering frequency can have negative effects on visual comfort [51]. However, raising the frequency to kHz levels and using high frequency controllers can reduce headaches [52], increase reading accuracy in spite of reducing reading speed [53] and enhance visual search performance [51]. Thus, installing the proper / right fluorescent lights can play an important role on students' output. Likewise, flickers from other appliance such as computers can cause enlarged saccadic movements in response [52].

CIBSE [46] suggests variant illuminance levels depending on classroom design on students' desks. The range changes between 300 and 500 lux. Rea [54] urges that aluminous higher than 1000 lux causes discomfort for students. According to the European Standard EN 15251 [34], the required lighting level is 300 lux.

Glare means visually brighter sight than the rest of the environment and it is one of the reasons causing trouble for visual comfort of students. Strong lighting, close positioning to the light source and weaker background light can cause glare on students' desks and consequently discomfort, even disability of sighting. Continual exposure to glare can even lead to headache and eyestrain.

Another reason for visual discomfort can come from projectors causing difficulties for students in perceiving images [55] as well as reflection from white or smartboards, in particular when the surface is lustrous.

Improper pattern frequency, contrasting color stripes and the size of window blinds may also cause stress [56], headache [57] and epileptic seizure [58].

VI. ACOUSTIC COMFORT

Sound is a function of vibration travelling as waves with varied frequencies and when the sound waves hit a surface, alteration in sound direction and energy causes reverberation. Reverberation, the reflected sound from any surface, will stay in until it is utterly absorbed or dissolute. These reflections from a surface can interfere with students' auditory perception. Despite little variations "experiments have shown that a healthy young person hears all sound frequencies from approximately 20 to 20,000 hertz" [59]. However, when the frequency gets very low and high in the audible range, it starts

causing hearing difficulties. For instance, when the sound frequency is lower than 500 Hz, it inclines to lead to unfavorable speech mask effects with consonants in particular and people with hearing challenge are more vulnerable to this effect [60].

Most classroom activities depend on conversation between students and the teacher that contributes great importance to the acoustic environment. Teachers are expected to have more student-oriented lessons and base their lessons more on practice rather than theory. Moreover, we are moving farther from the area of severely disciplined classes, schools and any educational atmosphere. Technology and the struggle to survive in the increasingly business-like educational atmosphere force educational institutions to use more and more technological gadgets that produce higher sound pollution in learning environment. Another important issue is that global warming, higher level thermal systems and improving living standards demand in more buildings and schools / classrooms HVAC systems that add to the distracting background noise in classrooms [61]. Environmental acoustic noise, especially during social science lessons will not only impede students' comprehension and consequently success level but also behavior patterns owing to lower attention and classroom discipline. It has been shown that with improved room acoustic conditions the students´ social behavior becomes calmer and the teachers experience lower physiological load (heart rate) as well as less fatigue [62].

Acoustic pollution seems to persevere in educational environments unless classrooms are acoustically designed, effects of acoustic pollution – particularly on young students' learning abilities - are taken into consideration and school administrations rely only on teachers and students for noise in classrooms. Nelson [63] states that students with attention, reading, learning or hearing difficulties, students under 13 and students using a language as the second one suffer more from the poor acoustic environment. Teachers are also affected by poor acoustic conditions because increasing their voice may lead to some vocal diseases and fatigue. However, it should be kept in mind that younger learners' speech lucidity is lower than adults and acoustic environment of classrooms are to be build or organized according to younger students [60]. According to the same source, noise from neighboring places, echoing sounds, HVAC noise and outdoor noise are sources of acoustic pollution. Ceiling & Interior Systems Construction Association (CISCA) in its white paper 'Acoustics in Schools' prepared by the InformeDesign® Research Desk at the University of Minnesota [64] add that reverberation, unabsorbed sound waves from surfaces and 'signal-to-noise ratios' which are lowest at the back of the classroom are other acoustic pollution factors.

"The acoustic conditions in schools are controlled by Part E of the Building Regulations, School Premises Regulations and the Independent School Standards, which apply to new and existing schools. School premises are also subject to the Equality Act Ref.6" [65]. As in the same source, Department for Education (DfE) informs that "Requirement E4 from Part E of Schedule 1 to the Building Regulations 2000 [38] (as amended by Statutory Instrument, SI 2002/2871) states that each room or other space in a school building shall be designed and constructed in such a way that it has the acoustic conditions and the insulation against disturbance by noise appropriate to its intended use.*"* Ref.3 in approved Document 4 states "In the Secretary of State's view the normal way of satisfying Requirement E4 will be to meet the values for sound insulation, reverberation time and internal ambient noise which are given in section 1 of Building Bulletin 93 'The Acoustic Design of Schools', produced by DfES" [65]. According to the same source, "Upper limits for indoor ambient noise level, LAeq,30mins" for classrooms should not exceed 35 dB in classrooms, breakout areas and lecture rooms, 40 dB in libraries, science laboratories and sports halls, and 45 dB in corridors, staircases, locker rooms, staff rooms, medical rooms and dining rooms (pp. 10-11).

The School Premises Regulations and Independent School Standards [66] comprise almost the same applies to both new and existing school buildings and contain a similar account. The Independent School Standards and School Premises Regulations pay great attention to speech intelligibility and operational noise levels in schools and all the measured acoustic comfort values are to be in accordance with the speech transmission index (STI) in new and refurbished/existing school buildings. The regulations from nursery and community education to colleges of further education also cover;

- Equality Act for challenged students
- Teaching and non-teaching spaces
- New, refurbished/existing and temporary buildings
- Material changes of use

The following recommendations for the energy consuming items are supposed reduce acoustic pollution and consequently improve students' auditory perception in classrooms.

- Apply the School Premises Regulations and Independent School Standards as much as possible.
- Locate and place energy-consuming and possibly noise-producing equipment such as printers, CD players and computers accordingly to reduce acoustic noise.
- Balance equipment well and pad them softly for them to produce less vibration noise.
- Prefer fans with low velocities for less noise.
- Enclose instructional equipment with noise isolation near classroom areas.
- Keep HVAC, instructional and mechanical equipment as far as possible from listening/speaking activity areas. Classrooms in the United States typically have speech intelligibility ratings of 75% or less, meaning every fourth spoken word is not understood [67].
- Prioritize natural ventilation systems when possible.
- Use isolation and plastic supports for the pipes, joints and other structural material to reduce vibration noise from the building.
- Take regular maintenance precautions for school equipment.

- Prefer quieter lighting systems in classrooms.

VII. Conclusion

School environment plays a significant role on students' and teachers' wellbeing and outcome. Although it is a multidimensional concept, thermal, air quality, visual and acoustic comforts are key components of school environment. It is clear that it is difficult to acquire desired results without psychologically and physically appropriate conditions. It can be derived from the above-mentioned literature that desirable indoor temperature should be between 20°C and 25.5°C, air humidity between 30% and 60% depending on the season, air ventilation between 15 and 60 cubic feet per minute of outdoor air for each person, CO2 levels less than 700 parts per million (ppm) above ground levels and illuminance levels between 300 and 500 lux. These figures are given below in Table 1 although it should be kept in mind that they may vary in accordance with outside and individual conditions.

Table 1: Desirable Indoor Conditions

DESIRABLE INDOOR CONDITIONS	MIN.	MAX.
Indoor Temperature	20°C	25.5°C
Air Humidity (cubic feet per minute of outdoor air for each person)	30%	60%
Air Ventilation (cubic feet per minute of outdoor air for each person)	15	60
CO2 Level (parts per million above ground levels)		700
Illuminance Level (lux)	300	500
Sound Frequency (Hz)	500	
Ambient Noise Level, LAeq,30mins (in classrooms, breakout areas and lecture rooms)		35 dB
Ambient Noise Level, LAeq,30mins (in libraries, science laboratories and sports halls)		40 dB
Ambient Noise Level, LAeq,30mins (in corridors, staircases, locker rooms, staff rooms, medical rooms and dining rooms)		45 dB

Otherwise, inappropriate school environmental conditions lead to some disorders such as attention loss, visual discomfort, unfavorable speech mask effect, high level of absenteeism and most importantly communicable diseases. In addition, workplace sick syndrome becomes an obstacle in front of an individual's wellbeing and productivity. It is also worth mentioning that making the use of natural sources such sunlight and wind-driven ventilation should be taken into consideration.

The first step to prevent negative effects of poor school environment should be collecting the current environmental data at least concerning four basic factors as thermal, indoor air quality, visual and acoustic comfort levels. The next step should be to applying to the international standards according to the regional conditions. Furthermore, building a school environment and energy policy can help school staff and students to develop awareness of environment and efficient energy consumption. To begin with, as school administrators may not be knowledgeable on the issue, it can be motivating to follow or adapt successful (inter)national samples, devote lessons to the issue, organize school conferences, competitions and science fairs.

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References

[1] N. Bernardi, and. C.C.K. Kowaltowski, *Environmental Comfort in School Buildings: Awareness and Participation of Users*, State University of Campinas, 2001, pp. 1-3.

[2] J. Pinder, J. Parkin, S. Austin, F. Duggan, M. Lansdale, P. Demian, et al., *The case for new academic workspaces*, Leicestershire: Department of Civil and Building Engineering, Loughborough University, 2009, pp. 21-27.

[3] P. M. Bluyssen, S. Janssen, L. H. Van Den Brink, and Y. de Kluizenaar, "Assessment of wellbeing in an indoor office environment*", Building and Environment*, Vol. 46(12), pp. 2632–2640, December 2011. http://dx.doi.org/10.1016/j.buildenv.2011.06.026

[4] A. Thewes, S. Maas, F. Scholzen, D. Waldmann, and A. Zürbes, "Field study on the energy consumption of school buildings in Luxembourg", *Energy and Buildings* 68(A), pp. 460–470, January 2014.

[5] J. Dobson, and K. Carter, "An Attitudinal and Behavioural Study of Scottish Pupils in Regards to Energy Consumption in Schools", *CIB World Building Congress*, United Kingdom, pp. 127–137, April 2010.

[6] P. Lourenço, M. D. Pinheiro, and T. Heitor, "From indicators to strategies: Key Performance Strategies for sustainable energy use in Portuguese school buildings", *Energy and Buildings* vol. 85, pp. 212-224, December 2014. http://dx.doi.org/10.1016/j.enbuild.2014.09.025

[7] V. Butala, & P. Novak, "Energy consumption and potential energy savings in old school buildings", *Energy Building*, vol. 29(3), pp. 241–246, January 1999. http://dx.doi.org/10.1016/S0378-7788(98)00062-0

[8] P. Roelofsen, "The impact of office environments on employee performance: The design of the workplace as a strategy for productivity enhancement", *Journal of Facilities Management*, vol. 1(3), pp. 247–264, June 2002. http://dx.doi.org/10.1108/14725960310807944

[9] K. Kamarruzzaman, and A.S.B.M. Tazila, "Thermal Comfort Assessment of a Classroom in Tropical Climate Conditions. Recent Advances in Energy", *Environment and Development*, pp. 157-159, 2013.

[10] Ch. Huizenga, and S. Abbaszadeh, L. Zagreus, *Air quality and thermal comfort in office buildings: Results of a large indoor environmental quality survey. Healthy buildings* Arens, Ed (2006), pp. 136.

[11] J. Myhren, and S. Holmberg, "Flow patterns and thermal comfort in a room with panel, floor and wall heating", *Energy and Buildings* 40 (4), pp. 524, 2008. http://dx.doi.org/10.1016/j.enbuild.2007.04.011

[12] *Thermal Environmental Conditions for Human Occupancy*, ANSI/ASHRAE Standard 55, pp. 12-17, 2013.

[13] Sh. Haddad, S.King, and P. Osmond, "Enhancing thermal comfort in school buildings", 10th International Healthy Buildings Conference, pp. 3, Volume: Proceedings, Healthy Buildings, At Brisbane 2012: Research Gate, 2012. Available: http://www.researchgate.net/publication/265051202)

[14] S. Szokolay, and V. Steven, *Introduction to Architectural Science: The Basis of Sustainable Design* (2nd ed.), 2010, pp. 16–22.

[15] C. Balaras, E. Dascalaki, A. Elena, and A. Gaglia, "HVAC and indoor thermal conditions in hospital operating rooms". *Energy and Buildings* 39 (4), pp. 454-470, April 2007.

[16] D.P. Wyon, and Wargocki, P., *Room temperature effects on office work. Creating the Productive Workplace*, 2nd edn, London, Taylor & Francis, 2006, pp. 181-192.

[17] W. Zeiler, and G. Boxem, "Effects of thermal activated building systems in schools on thermal comfort in winter". *Building and Environment*, vol. 44, issue 11, pp. 2308-2317, November 2009. http://dx.doi.org/10.1016/j.buildenv.2009.05.005

[18] H. Levin, "Physical factors in the indoor environment. Occupational medicine", Philadelphia, Pa.. 10 (1):59, pp. 62-63, 1995.

[19] A. Kwok, and C. Chun, "Thermal comfort in Japanese schools". *Solar Energy*, 74, pp. 245–252, March 2003.

[20] M. Frontczak, and P. Wargocki, "Literature survey on how different factors influence human comfort in indoor environments". *Building and Environment, 74(3), pp.* 922–937, March 2003.

[21] M. Elbayoumi., and N.A. Ramli, N.F.F. Yusof, and W.A. Madhoun, "Influence of seasonal variation on thermal comfort and ventilation rates in Gaza Strip climate", *Turkish Journal of Engineering and Environmental Sciences*, vol. 38(2), pp. 28, 2014. http://dx.doi.org/10.3906/muh-1402-1

[22] E.Z.E. Conceiçao, M.M.J.R. Lu´cio, A.E.B. Ruano, and E.M. Crispim, "Development of a temperature control model used in HVAC systems in school spaces in Mediterranean climate". *Building and Environment*, 44(5), pp. 871–877, May 2009.

[23] M.A. Humphreys, and J.F. Nicol, "Understanding the adaptive approach to thermal comfort", *ASHRAE Transactions*, 104 (1), pp. 991-1004, January 1998.

[24] B. Olesen, and K.C. Parsons, "Introduction to thermal comfort standards and to the proposed new version of EN ISO 7730". *Energy and Buildings*, 34 (6), pp. 537–548, July 2002.

[25] I. Hussein, and M.H.A. Rahman, "Field study on thermal comfort in Malaysia", *European Journal of Scientific Research*, Vol. 37, No. 1, pp.134-153, November 2009.

[26] J.M. Daisey, W.J. Angell, and M.G. Apte, "Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information", *Indoor Air*, 13, pp. 53–64, 2003. http://dx.doi.org/10.1034/j.1600-0668.2003.00153.x

[27] D. Clements-Croome, H. Awbi, Z. Bako-Biro, N. Kochhar, and M. Williams, "Ventilation rates in schools", *Building and Environment*, 43(3), pp. 362–367, 2008. http://dx.doi.org/10.1016/j.buildenv.2006.03.018

[28] P. Wargocki, and D.P. Wyon, "The effects of outdoor air supply rate and supply air filter condition in classrooms on the performance of schoolwork by children (RP-1257)". *HVAC & R Res*, vol. 13(2), pp. 165–191, March 2007. http://dx.doi.org/10.1080/10789669.2007.10390951

[29] O.A. Seppänen, W.J. Fisk, and M.J. Mendell, "Association of Ventilation Rates and CO2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings*", Indoor Air*, vol. 9(4), pp. 226-252, December 1999. http://dx.doi.org/10.1111/j.1600-0668.1999.00003.x

[30] A. Chaloulakou, and I. Mavroidis, "Comparison of indoor and outdoor concentrations of CO at a public school. Evaluation of an indoor air quality model", *Atmospheric Environment*, vol. 36(11), pp. 1769-1781, April 2002. http://dx.doi.org/10.1016/S1352-2310(02)00151-6

[31] P. Wargocki, and D.P. Wyon, "The Effects of Moderately Raised Classroom Temperatures and Classroom Ventilation Rate on the Performance of Schoolwork by Children", *HVAC&R Research*, vol. 13(2), pp. 193-220, March 2007.

[32] Building Energy Codes University, *ANSI/ASHRAE/IESNA Standard 90 1-2007*, , Section 6, pp. 69-155

[33] Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems, Supersedes EN 13779:2004, *EUROPEAN STANDARD, EN 13779*, April 2007, pp. 30-31.

[34] *Cense 2010, Information paper on EN 15251 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*, May 2007, pp. 4-6.

[35] *Indoor Air Quality Guidelines for Pennsylvania Schools*,Pennsylvania Department of Health, 1995, pp. 2-3.

[36] B.M. Jonesa & R. Kirbyb, *Indoor Air Quality in U.K. School Classrooms Ventilated by Natural Ventilation*, Windcatchers, 2012, pp. 4.

[37] A.K. Persily, "Evaluating Building IAQ and Ventilation with Indoor Carbon Dioxide", *ASHRAE Transactions*, 103, pp. 193-204, 1997.

[38] *ODPM (2006) Building Regulations 2000, Part F (Ventilation)*, Office of the Deputy Prime Minister, London, U.K., 2000.

[39] C. Godwin, and S. Batterman, "Indoor air quality in Michigan schools", *Indoor Air*, 17(2), pp. 109-121, April 2007.

[40] R.T. Hellwig, F. Antretter, A. Holm, and K. Sedlbauer, "Investigations into Indoor Environment Conditions and Natural Ventilation in School Buildings", *Bauphysik*, 31, pp. 89-98, 2009. http://dx.doi.org/10.1002/bapi.200910013

[41] *DfES (2002) Building Bulletin 95 – Schools for the Future, Department for Education and Skills*, London, U.K., 2002.

[42] J.B. Lyons, "The learning environment: do school facilities really affect a child's education?", *Learning by Design*, 11, pp. 10–13, 2002.

[43] H. Rittner, & M. Robbin, "Color and light in learning", *School Planning & Management*, 41(2), pp. 57–58, February 2002.

[44] F. Xue, "Flexible programs and evaluation study on Elementary School Joint Classrooms", Ph.D. thesis paper, Graduate Institute of Civil Engineering, National Taiwan University, 2002.

[45] D.H.W. Li, and S.L. Wong, "Day-lighting and energy implications due to shading effects from nearby buildings", *Applied Energy*, vol. 84(12), pp. 1199–1209, December 2007. http://dx.doi.org/10.1016/j.apenergy.2007.04.005

[46] D.H.W. Li, and J.C. Lam, "Evaluation of lighting performance in office buildings with day-lighting controls", *Energy and Buildings* 33(8), pp. 793–803, October 2001.

[47] *CIBSE. (2004). Code for lighting. London: CIBSE*.

[48] DfEE. "Lighting design for schools", Vol. 90, 1999, London: The Stationery Office.

[49] M.E. Schreiber, "Lighting alternatives: considerations for child care centres", *Young Children*, 51(4), pp. 11–13, 1996.

[50] M. Shapiro, d. Roth, D., and A. Marcus, "The effect of lighting on the behavior of children who are developmentally disabled", *Journal of International Special Needs Education*, 4, pp. 19–23, 2001.

[51] M. Jaen, J. Sandoval, E. Colombo, and T. Troscianko, "Office workers' visual performance and temporal modulation of fluorescent lighting", *Leukos the Journal of the Illuminating Engineering Society of North America vol.* 1(4), pp. 27–46, September 2013. http://dx.doi.org/10.1582/LEUKOS.2004.01.04.002

[52] A. Wilkins, M. Nimmo-Smith, A. Slater, and L. Bedocs, "Fluorescent lighting, headaches and eyestrain", *Lighting Research and Technology*, 21(1), pp. 11–18, 1989. http://dx.doi.org/10.1177/096032718902100102

[53] R. Küller, and T. Laike, "The impact of flicker from fluorescent lighting on wellbeing, performance and physiological arousal", *Ergonomics*, vol. 41(4), pp. 433–447, May 1998. http://dx.doi.org/10.1080/001401398186928

[54] M.S. Rea, "Effects of Haidinger's Brushes on Visual Performance", *Journal of the Illuminating Engineering Society*, 12(3), pp. 197–203, 1983. http://dx.doi.org/10.1080/00994480.1983.10748831

[55] I. Hall, and S. Higgins, "Primary school students' perceptions of interactive whiteboards", *Journal of Computer Assisted Learning*, 21(2), pp. 102–117, April 2005.

[56] A. Wilkins, *Visual stress*. Oxford University Press, Oxford, 1995, pp. 73. http://dx.doi.org/10.1093/acprof:oso/9780198521747.001.0001

[57] D.E. Harle, A.J. Shepherd, and B.J. Evans, "Visual stimuli are common triggers of migraine and are associated with pattern glare", *Headache*, 46(9), pp. 1431–1440, October 2006.

[58] G. W. Juette, and L. E. Zeffanella, "Radio noise currents n short sections on bundle conductors," presented at the IEEE Summer Power Meeting, Dallas, TX, June 22-27, 1990.

[59] J.D. Cutnell, and K.W. Johnson, *Physics*, 4th ed. New York: Wiley, 1998, pp. 466.

[60] Committee to Review and Assess the Health and Productivity Benefits of Green Schools, *Acoustical quality, student learning, and teacher health. In Green schools: Attributes for health and learning*, Washington, DC: The National Academies Press, 2006, pp. 92-104.

[61] P. Nelson, "The changing demand for improved acoustics in our schools", *The Volta Review*, 101(5), pp. 23-31, 1999.

[62] M. Oberdörster, and G. Tiesler, "Acoustic Ergonomics of School. Research Report of the Federal Institute for Occupational Safety and Health", *Research Fb 1071*, University of Bremen, 2006.

[63] N. Nelson, "Sound in the classroom: Why children need quiet", *ASHRAE Journal*, vol. 45(2), pp. 22-28, February 2003.

[64] *Acoustics in Schools*, Ceiling & Interior Systems Construction Association CISCA, Prepared by the InformeDesign® Research Desk at the University of Minnesota under contract to CISCA, 2009, pp. 3.

[65] Department for Education and Skills, *Acoustic design of schools: performance standards*, Building bulletin 93 A Design Guide, 2015, pp. 8-12.

[66] Department for Education and Skills, *Advice on standards for school premises For local authorities, proprietors, school leaders, school staff and governing bodie*", DFE-00311-2013, London, pp. 5-14, 2013.

[67] B. Seep, R. Glosemeyer, E. Hulce, M. Linn, and P. Aytar, "Classroom acoustics: A resource for creating learning environments with desirable listening conditions", Melville, NY: Acoustical Society of America, 2000. (as in CISCA, 2009. Acoustics in Schools Prepared by the InformeDesign® Research Desk at the University of Minnesota under contract to CISCA. P. 3)