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The Case for Hybrid Ventilated Primary Schools in Ho Chi Minh City in Vietnam

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ABSTRACT: This study investigates indoor environmental quality and users' perception in 14 classrooms of a mixed-mode ventilated primary school in Ho Chi Minh City, Vietnam, during the rainy season by qualitative and quantitative research methods. Spot and long-term measurements were recorded, covering a range of environmental parameters such as air temperature, relative humidity, CO_2 concentration level, illuminance and sound level. A questionnaire was conducted and answered by 451 children (eight to eleven year olds) to investigate their perception of the thermal and visual comfort, indoor air quality, noise and overall comfort in the classrooms. In addition, 14 teachers were asked to inform the study about their experiences and behaviours in the classrooms. The results were analysed by cross relating the measured environmental conditions and the comfort vote on a seven-point scale.
Keywords: indoor environmental quality, hybrid ventilation, primary school

INTRODUCTION

There is a growing body of literature that recognises the importance of indoor environmental quality to occupants' activities in buildings. Previous studies reported that indoor environments significantly influence people's performance and productivity (Fisk, 2000), especially for students in schools (Mendell and Heath, 2005). As children spend most of time in schools, indoor environmental quality significantly and directly influences their study.

Previous studies on indoor environmental quality undertaken in the period between 1977-2009 have been summarized and analysed by Frontczak and Wargocki (2011). Their study indicated that thermal comfort was the most important factor influencing the overall indoor comfort. Satisfaction with indoor environmental quality, indoor air quality, thermal and visual environment could be increased by improving the occupants' interactions with the buildings. The literature also suggested that there was no influence of occupant age on overall satisfaction with indoor environmental quality. A number of studies have been undertaken about each factor of indoor environmental quality for children. However, only a limited number of researches have focussed on indoor environmental quality in primary schools in recent years. Fadeyi et al. (2014) conducted a field measurement of indoor environment. Not only CO_2 concentration but also the other indoor pollutants were monitored continuously. However, the evaluation was completely based on the current international standard (BB 101 (2006), BB 93 (2015), ASHRAE Standard 55 (2004)…) and the subjective evaluation had not been carried out. Dorizas et al. (2015) assessed the indoor environmental quality in the conjunction with the pupils learning performance and energy consumption. Children believed that satisfactory IAQ, lighting and acoustics enhanced their performance. Additionally children's health was affected directly by high levels of particulate matter and CO_2 concentration. De Giuli et al. (2015) proposed a well-designed methodology to evaluate not only human's satisfaction about indoor environmental quality but also occupant-building interaction based on the case studies of Italian primary schools. CO_2 concentrations and sound level were not continuously monitored and consequently the study could not give the full picture of indoor air quality and acoustic environment in the long term.

In Vietnam, there has been some research undertaken about thermal comfort in residential buildings (Nguyen, 2013), lighting in schools (Tran, 2010). However, nothing to date presents a comprehensive research study on the indoor environmental quality in buildings. In addition there is a lack of information on the environmental design performance of buildings designed for younger children in Vietnam. Nowadays, using air conditioning systems in order to obtain the indoor comfort has become more popular in primary schools in Ho Chi Minh City (HCMC) due to the hot and humid climate. However, it leads to high levels of energy consumption and environmental problems in the primary schools as well as potential adverse effects on children's health and performance in the long time such as asthma, allergy and respiratory infections. Therefore developing standards for Vietnamese primary school design to meet acceptable comfort levels without the need of air conditioner is an important task for architects and researchers. As the initial step of a larger research project, the work presented in this paper aims to evaluate the indoor environmental quality in a mixed-mode ventilated primary school. Additionally the work

presents preliminary investigations of children's perceptions of the current environmental conditions in their school in HCMC. Both qualitative and quantitative methods were used in this investigation. This field study is part of a larger research project developing environmental design standards for primary school in HCMC in Vietnam.

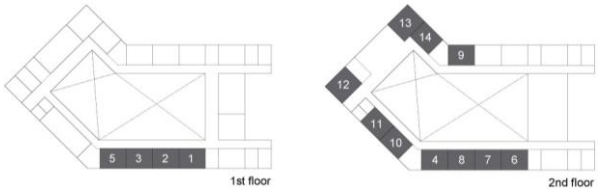

Figure 1 Schematic plans of primary school and investigated classrooms

Figure 2 Pictures of typical classroom

CASE STUDY

The primary school investigated is located in a medium density residential area of a central district in HCMC. There are 26 class rooms with approximately 31 pupils per class on average. The typical room size is 46.5m^2. The floor to ceiling height is 3.3m^2 (see Figure 1 and 2). The walls are made of double bricks without thermal insulation. Doors and windows of the classrooms have single glazing and steel frames. There are ceiling fans, curtains on the windows and artificial lighting systems using eight fluorescent lamps. The academic year is from 15 August to 31 May 2015. The school time is 07:00-10:10 and 13:50-16:10 on Monday to Friday.

In average, children's clothing insulation level is on average 0.55clo. The weather over the four days of investigation was similar. There is no wind and clear sky during the study period.

Table 1 Recommended criteria for indoor environmental quality in classrooms

Category	Thermal conditions (^{o}C)		IAQ, CO_2 level (ppm)	Lighting (lux)	Acoustic environment (dB)
	EN15251 (CEN, 2007)	ASHRAE Standard 55 (ASHRAE, 2004)	Building Bulletin 101 (DfE, 2006)	EN15251 (CEN, 2007)	Building Bulletin 93 (DfE, 2015)
I	23.5-25.5	T_{comf}=0.31 $T_{(a,out)}$+17.8	<1000	>300	<55
II	23.0-26.0				
III	22.0-27.0				
IV	<22.0 or >27.0				

METHODOLOGY

Two modules of a NETATMO environment/weather station were installed in classroom 3 (see Figure 1) in order to conduct long-term in-situ measurement of environmental conditions. The outdoor unit records the data of outside air temperature and relative humidity while the internal one monitors the parameters of indoor environmental quality such as temperature, relative humidity, CO_2 concentration level, sound level and atmospheric air pressure. The data is recorded every five minutes. Data has been continuously recorded since June 2015. The NETAMO system has the following accuracy of ±0.3^{o}C for temperature, ±3% for humidity, ±50ppm for CO_2 level. Environmental Meter conducted spot point measurements of lighting, temperature, relative humidity and sound level in and outside the classrooms. In the classrooms, nine spot point measurements were recorded at locations based on the studying plane of pupils, which is 670mm high. A questionnaire was carried out at the same time as the spot measurements were made within the occupied classrooms. The questionnaire focused only on children from eight to 11 years old due to the reading skills of the pupils. The questionnaire contained seven key questions and was formulated in a way which could help children respond more easily. Four of the questions were on indoor environmental quality evaluation based on the seven-point judgement scale. The other yes-no questions were about overall comfort, children's 'sleepiness' and their perception about the classrooms. Teachers took part in the survey in order to supply more information about the long-term evaluation of indoor environmental quality and occupants' behaviours.

RESULTS AND DISCUSSION

Thermal comfort

The results from the measurements showed that most of children felt 'neutral' or 'cool' for a temperature range **from 27.8^{o}C to 32.3^{o}C** and a relative humidity range **from 65.7% to 85.3%** in their classrooms. The Thermal Sensation Mean Vote of (-0.43) implied that the tendency of children's feeling is comfortably cool. However, based on the temperature from the spot measurement, all classrooms were classified as Category IV, which is out of the range for good indoor environmental quality. The results from long-term monitoring showed that classroom 3 was also classified in category IV for 96% of the school time during the period from July 2015 to September 2015. In addition,

occupants experienced high temperatures in the building as defined in CEN (2007, p.13). There is a conflict between the results from the objective and subjective approach undertaken in this study. The findings provide some evidences that EN 15251 may not be applicable for young children in Vietnam. Furthermore, it also suggests that Vietnamese children may be less sensitive to high temperatures. For Humphreys observations (1977) on UK children from seven to nine years old, the results showed that the comfort temperature could be **from 23°C to 25°C**. In comparison with the current results, it proposes that Vietnamese children may adapt much better to the hotter climate they are familiar with.

As shown in Figure 4, the temperature was relatively unsteady during rainy season. The outdoor temperature ranges from 26°C to 35°C while the range of the indoor temperature in classroom 3 is 26-33°C. In addition, the mean monthly temperature outside was 1.2°C higher than it was inside. These results indicate that the building envelopes may contribute to providing cooler indoor environment temperatures.

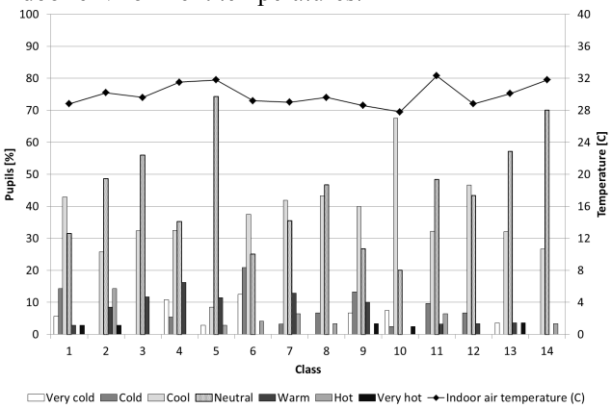

Figure 3 Children's thermal sensation compared with the indoor air temperature in the rainy season

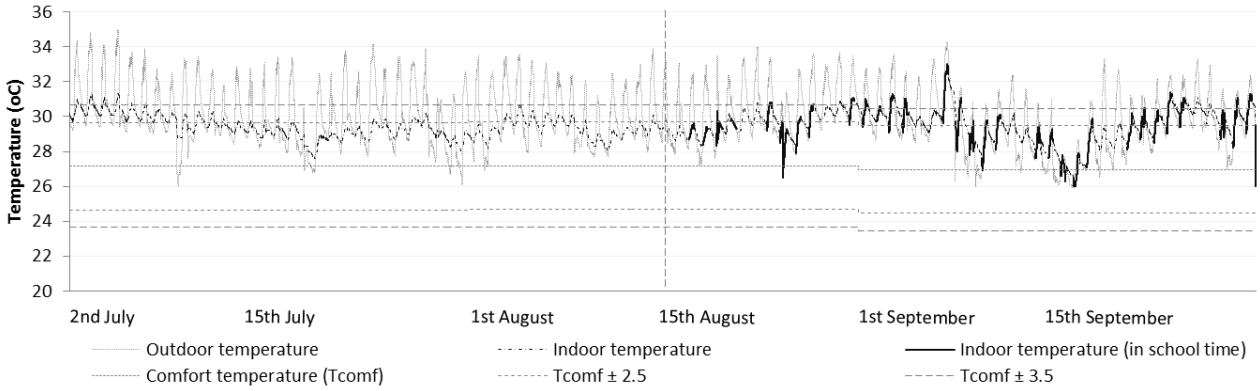

Figure 4 Temperature values during the period of 1st July – 30th September 2015 at investigated primary school

Opening doors and windows allows unconditioned outdoor air coming into the room directly and using ceiling fans is a supplementary cooling method. Therefore, the adaptive approach from ASHRAE (2004) for naturally ventilated building was applied in order to evaluate the case of classroom 3. As shown in Figure 4, with the thermal comfort zone band of 5°C, a comfort condition is achieved for 50.6% of school time. If this band is extended to 7°C, people feel thermally comfortable for 79.7% of school time. In both cases, the comfort condition fell into the warm zone. Thus occupants could experience even hotter and more uncomfortable environments in rainy season. During the investigation time in classroom 3, the indoor temperature was 29.6°C, which is in the wider and more easily achievable comfort zone. Surprisingly, if the thermal sensation votes were divided into satisfaction categories (±3, ±2: dissatisfied; 0, ±1: satisfied), 100% children in classroom 3 felt comfortable at that time. 55.9% votes were for "neutral" feeling. Thermal sensation mean votes of (-0.21) implied that children might feel cool in this classroom. The incomparable results between the questionnaire and measurements taken raised the possibility that ASHRAE Standard 55 (2004), as well as EN 15251 (2007), cannot apply to the design of buildings for children in Vietnam.

Indoor air quality

CO_2 concentration level was under the recommended value of 1000ppm in classroom 3 from July 2015 to September 2015. Furthermore, most of children (95.3%) voted 'no odour' in their classroom during the survey in Sep 2015, as shown in Figure 6. This result proposed that indoor air quality of the school, in term of CO_2 concentration and odour, was acceptable for teaching and learning activities. This result may be explained by the fact that opening doors/windows and using ceiling fans enhanced the air change and air movement in the classrooms. In addition, good outdoor air quality could cause the low level of CO_2 concentration and odours.

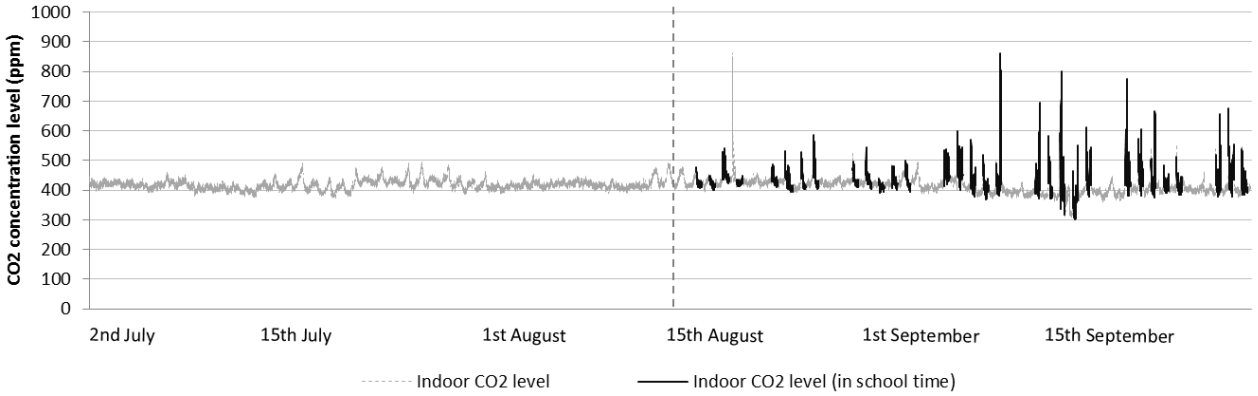

Figure 5 CO_2 concentration level during the period of 1st July – 30th September 2015 at investigated primary school

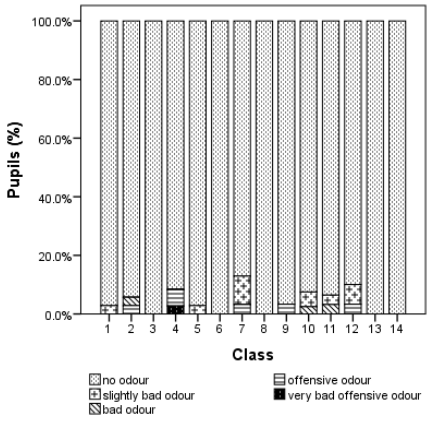

Figure 6 Percentage of vote for odour in the classrooms

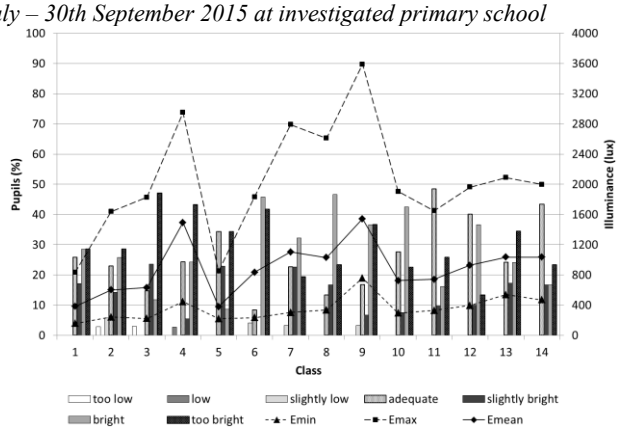

Figure 7 Children's visual comfort vote compared with indoor illuminance in the classrooms

Visual comfort

To understand the usual conditions of lighting, the classrooms with artificial lighting systems were investigated. The illuminance from eight fluorescent lamps of 2000-3000lm per each was distributed throughout each classroom. The results from the spot measurements showed that the mean illuminance in each classroom was above the recommended value of 300lux. Therefore, the visual environment, in term of illuminance, is acceptable for learning and teaching activities. However, the illuminance distribution in classrooms was non uniform (below 0.6). The desks near the doors or windows received significant additional daylight while the desks in the middle of classrooms received very little daylight and were mostly lit from the artificial lighting. The distributions of the artificial lighting systems were similar for all the classrooms. The average minimum illuminance (353.57lux) in spaces could be considered as the main distribution from the artificial lighting system. The average illuminances of classrooms on the first floor were lower than on the second floor. The trees along both sides of the buildings were the possible cause of this difference in daylight levels. At the first floor level, the branches are denser and interrupt the daylight entering the rooms. The classrooms with windows facing North had better lighting quality and distribution while the ones with South-facing windows, even on the same floor, had lower uniformity ratio. This result can be explained by the fact that the sunlight came from the North in this period of a year. Another possible explanation for this is that the corridors on the other side of the classrooms reduce the lighting coming into the classroom.

The lighting Mean Vote of 1.57 indicated that children felt the light levels were almost bright or even too bright on their desks. The results also showed that there is no clear relationship between the actual lighting value and the mean vote in each classroom. Therefore, it is possible that children voting "bright" or "too bright" related to visual discomfort issues, such as glare, rather than the quantity of light.

Acoustic comfort

The results from the spot measurement showed that the sound level ranged from 54.1dBA to 78.2dBA. The majority of children voted neutral for noise in the classrooms. The Mean Vote of (-0.05) showed that the tendency of the children's response is 'a bit noisy' in classrooms. According to WHO (2009), children exposed to the environment of over 55dBA in 8 hours had 'significantly decreased attention'. Thus the overall noise could be unsuitable for studying concentration.

The primary school was unoccupied until 15th August. Therefore the measured sound during that period could be considered as background noise. As shown in **Figure 9**, the sound level is under 55dB for almost all of the unoccupied time. Thus the background noise could be acceptable for learning activities. During school time, the noise measured in the classroom 3 increased significantly and the range of the sound level was 36-81dB. Children generally voted 'neutral' for noise level in classroom 3 on the day of investigation. In this mixed mode building, when the doors and windows were opened during the school time, the classrooms were exposed from the surrounding noise. While the background noise was not problematic, the source of disturbing noise may came from inside the school, the next classrooms or inside the classroom itself from the pupils. However, in general, children felt neutral about noise in the classrooms. It is possible that they were familiar with the noisy environment.

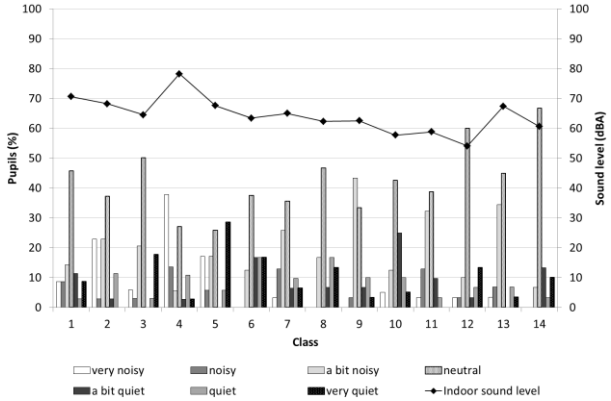

Figure 8 Votes of noise level compared with indoor sound level in the classrooms

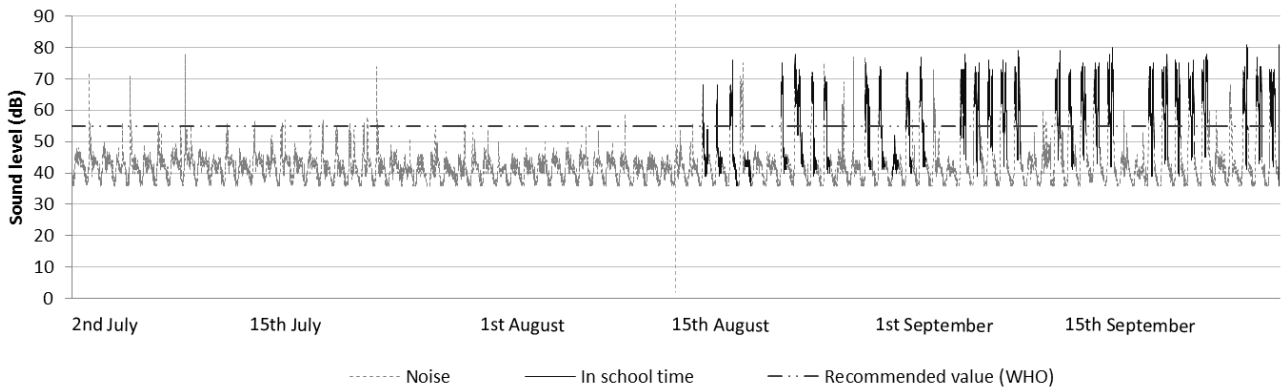

Figure 9 Sound level during the period of 1st July – 30th September 2015 at investigated primary school

Indoor environmental quality

The results showed that 95.6% children like their classrooms. It implied that they cared about the classroom and their answers were more reliable. 95.1% children perceived comfortable indoor environmental quality although they did not feel 'neutral' for all factors. it can be explained that some factors could have more weighted influences to children's overall comfort than the others. In addition, there could be other issues which affected indoor comfort besides the physical elements of environment. The question about sleepiness was to determine the alertness of children at the investigated time. The responses gave the suggestions about the effect of the current indoor condition on children. There were some possible factors affecting directly on children's alertness and performance. Most of children (91.8%) felt alert/conscious in the classroom. There a strong relationship between indoor comfort and children's alertness condition.

Users' behaviour

In general, teachers evaluated good current indoor environmental quality, especially for indoor air quality and noise. However, their experiences in the long term raised up some issues. Children feel comfortable and slightly cold at the time of investigation. Teachers feel hot and preferred to be cooler since they use the building for longer periods than the children. It could be explained that teachers may be affected by the hotter conditions for longer periods of time and consequently perceive to be uncomfortable. The teachers generally perceived that there was more natural daylight than artificial lighting in the classrooms. However, the lighting systems were almost always in use. It can be explained that teachers recognized natural lighting more because the daylight levels and changes in daylight levels had a strong influences on the overall environment that teachers perceived. The survey also provided feedback on how occupants react to change in the environment when they feel uncomfortable in the classroom. The environments are largely controlled by of the teachers who control the fans, doors and lights. The children have little active control on their environment for safety reasons although they do have more chance to open/close the curtains and windows due to the proximity to their desks. Therefore, the fans,

lights and doors are usually used according to the teacher preferences. The windows were open almost all the time to provide natural ventilation. In the comparison with the other building elements which teachers control mostly, the curtains are used more flexible by children.

CONCLUSION AND DISCUSSION

This study was undertaken to evaluate the current conditions and users' perception of indoor environmental quality in a mixed-mode ventilated primary school which operates in the free-running mode whenever possible and using ceiling fans is a supplementary cooling method. Although the investigation was conducted in the rainy season, which is neither the hottest or coldest time in the year, the results show some significant findings.

Mixed-mode lighting and CO_2 concentration levels were acceptable for learning spaces according to recommended values from international standards. However, the measurements showed that thermal and acoustic environments were not satisfactory according to current standards. The results from a questionnaire showed that children felt comfortable with the overall condition and perceived acceptable levels of temperature, odour and noise. The children in the study also experienced some visual discomfort. According to the subjective responses, there is no clear relationship between overall comfort and each factor of indoor environmental quality. There are conflicts between the results from the quantitative measurements and qualitative subjective responses of the thermal, visual and acoustic environment. The findings of this fieldwork suggest that the current standards for thermal and acoustic comfort may not be applicable for children in Vietnam. Moreover, the building was not well-designed for daylighting and shading devices should be installed in order to prevent glare.

In general the teachers' responses were similar to children's. However, they perceived higher temperatures. The children were passive in changing the indoor environment because the teachers mainly controlled the active building elements.

The research presented here is a starting point for further enhanced studies on design and indoor environmental quality for children's learning spaces in Vietnam. Unfortunately, the results to date are currently not strong enough to conclude about the recommended comfort criteria in Vietnamese schools. Further studies are required in the hottest and coldest seasons and in more schools in order to complete the building evaluation to inform design parameters.

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