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Indoor Air Quality and thermal comfort of working squares in schools

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Abstract

Indoor air quality and thermal comfort in schools are now almost universally worse than the relevant standards and building codes stipulate that they should be. The Dutch government therefore proposed new regulations to assure children's health in school. These led a big improvement. Another trend in new designed schools is a central space used as a central work place for multiple classrooms, to enable pupils to work individual outside the classroom. There are no regulation concerning these working squares. Therefor CO_2 concentrations were measured in four working squares for seven days, continually. The results have shown that learning areas in these newly built primary schools have very good IAQ and satisfying thermal comfort during heating period, mean value of CO_2 concentration at breathing zone to below 800 ppm during 95% of weekly school time. The conclusion is that the four learning squares in primary schools achieved satisfying results during measuring period.

Keywords – schools, learning squares, IAQ, thermal comfort

1. Introduction

With the trend of building sustainable schools, new designed schools are built more air tight and with minimum window openings. The indoor air quality (IAQ) is affected by this development. The main purpose of school ventilation is to create a healthy indoor environmental conditions that reduce the risk of health problems among pupils and ensure their comfort requirement for optimal performance. As children are more vulnerable than grownups it is therefore important that schools have good indoor air quality (IAQ). Carbon dioxide (CO_2) concentration has become widely used as an indicator of IAQ though CO_2 itself is not an indoor air pollutant, and was taken as surrogate for the ventilation rate [1] Elevated CO_2 levels indicate low ventilation rates [2,3,4,5] and thus elevated concentration of other pollutants and the bio effluents from children, leading to poor IAQ. Besides, mean value of indoor CO_2 level [6] is used for evaluating the quality of ventilation. Most of the data published in the scientific literature indicate that classroom ventilation in many schools is still inadequate. However, the new Dutch regulations which came in practice in the recent years led to a major improvement. And even in highly insulated and air tight nZEB schools, were the ventilation is crucial for a good IAQ, the results are rather good [7] The new guideline 'Freshly Schools' RVO 2015 [8] states the required CO_2 concentrations inside independent of the outside concentrations and is therefore rather strict. The mentioned concentrations are in principle based on the maximum occupancy of 32 pupils and a teacher.

Table 1. Program of demands for 'Fresh Schools' RVO 2015[8] different classes for IAQ regarding CO2-content

	Class C (acceptable)	Class B (good)	Class A (very good)
Ventilation	≤ 1200 PPM	≤ 950 PPM	≤ 800 PPM

In recent years attention has mainly focused on classroom IAQ, as it is still the most common functional space, occupying the largest area of every school building, and hosting the largest part of daily activities and occupants. Additional articles are devoted to other functional spaces of school buildings. Recent publications address atria [9], staff rooms and auditoria [10], and sport halls [11]. No publications were found that emphasize some of the regular though specific features of classroom wings, such as the learning square or corridors.

In the Netherlands, besides classroom, there is a space for students learning as well, called learning square literally translated from Dutch word: leerplein. The most important function of the learning square is that students can work individually or cooperatively on their assignments, secondary functions can be reading or recreation area. Learning square usually links to several classrooms, when the door of classroom opened, teachers therefore can monitor the students working condition in learning square. In the past, corridor use to play this function. In the programme of fresh school, it suggested a maximum 25 students will be present in the learning square. This estimation is based on the use of two classrooms with an average of 25 children. A maximum of 50% and one or two teachers that will be using the learning square. The real number of students will vary during the day rapidly as students work out assignments and then go back to the classroom, or sometimes doing other small activities, such as having lunch. The size of the learning square and the number of work stations in it are associated with the size of the school, see Fig. 1.

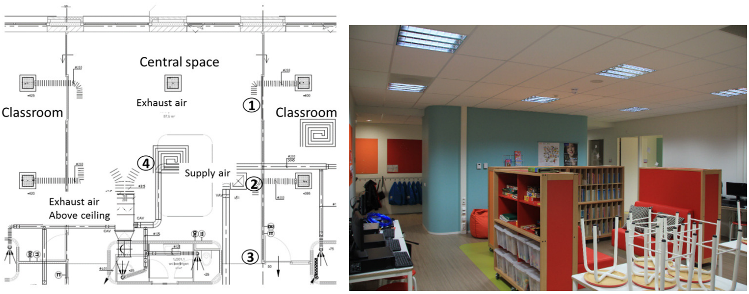

Fig. 1 An example of a working square connected to different classrooms.

The learning square is still in development, as there are no legal requirements or obligations for reference which make designers often do not know how to implement a learning square appropriately. One of the most dominant features of a learning square is its public usability, meaning a good required level of IAQ as youngsters are exposed to along the major period of their growing up years [12]. The paper based on this point decided to do the field measurement to get to know whether IAQ of learning square in practice confronts to its designed value. Therefore, measurement data include CO_2 concentrations (hereinafter referred to as IAQ), temperature and relative humidity.

2. Methodology

Four field measurements were carried out in newly built fresh schools, which are all mechanically ventilated and in operation in all learning squares. To determine whether there is high CO_2 level in learning square during heating season, and whether IAQ (refer to CO_2 concentration) of learning square meet the required corresponding level by existing ventilation system. As poor ventilation most often occurs in heating season in the Netherlands, in four newly built fresh schools it was determined to take one week measurements in the period of January 2015 to March, to better evaluate IAQ and ventilation performance.

Table 2. Construction year and measurement period of each school

School	Build	Measurement period	Ventilation system
A	October 2011	March 2015	CO_2-based demand controlled VAV
B	October 2013	January 2015	CO_2-based demand controlled VAV
C	September 2014	February 2015	Temperature controlled VAV
D	September 2014	January 2015	CO_2-based demand controlled VAV

The hygrothermal performance of the learning square was evaluated by the continuous measurement of temperature and relative humidity inside the learning squares approximately in the middle of the learning square and the IAQ was assessed, during the same period, by the CO_2 concentration.

Five different parameters were measured: indoor temperature, radiant temperature, relative humidity, indoor and outdoor CO_2 concentration. Indoor CO_2 levels at breathing zone were monitored in two locations, one was close to the occupied zone approximately in the middle of the learning square, and the other was located on an unoccupied student desk, at seated breathing height, which was 1.1m above the floor, away from the windows and doors. Another two sensors were put in the supply grill and exhaust grill to better analyse data. Moreover, one set of the equipment was used to measure outdoor CO_2 levels. Basic information of equipment can be seen in table 3.

Table 3. Information of measurement equipment

Nr.	Unit	Sensor type	Range	Accuracy	Position
1	CO_2 (ppm)	PP-systems SBA5	0-2.000	<1% of total range	supply grill exhaust grill workplace 1@1,1m workplace 2@1,1m
2	CO_2 (ppm)	E+E80	0-2000	±50	Workplace 1
3	T (°C)	E+E80	0-50 °C	±0.3	Workplace 1
4	RH (%)	E+E80	10-90%	±3%	Workplace 1
5	Black globe T (°C)	Black sphere ntc u-type	0-50 °C	±0.05	Workplace 1
6	v (m/s)	HT-428	.02-1.0	±1%	Workplace 1
7	T (°C)	ntc u-type	0-50 °C	±0.3	supply grill exhaust grill workplace 1@1,1m workplace 2@1,1m
8	Debiet grill V (m3/h)	Flowfinder ACIN MK2	10..550	±3%	Grills
9	Data logger	Grant 2020	1 read/sec	±0.05	Workplace 1

3. Results

Fig. 2-5 show plots of CO_2 levels recorded in the occupied zone of a characteristic and representative day in all learning squares based on the recorded 3-min average values during measuring period. The purple curve and the yellow curve stands for CO_2 level of at breathing level and background level of learning square, respectively.

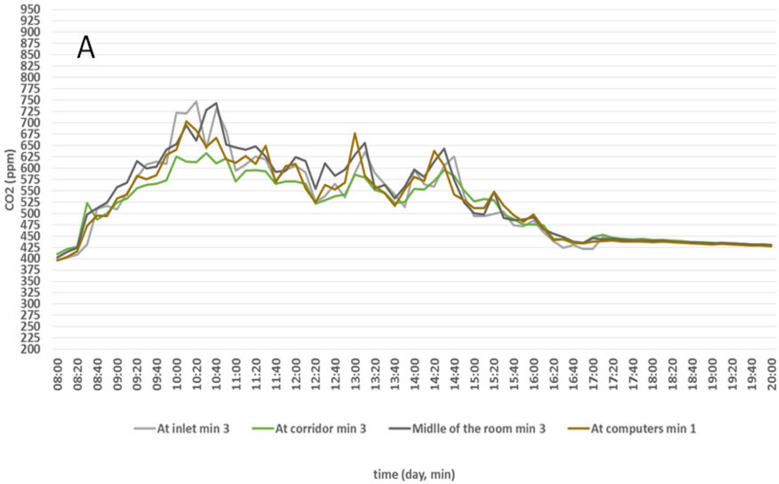

Fig. 2 CO_2 levels learning squares over a period of a working day recorded in school A.

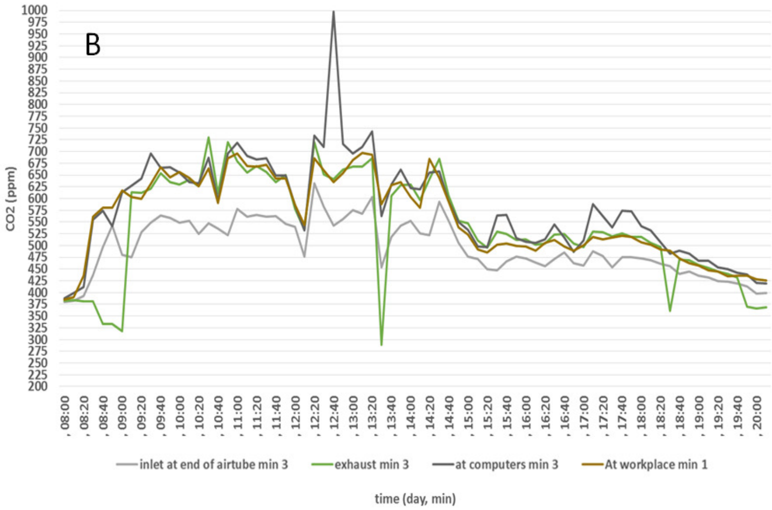

Fig. 3 CO_2 levels learning squares over a period of a working day recorded in school B .

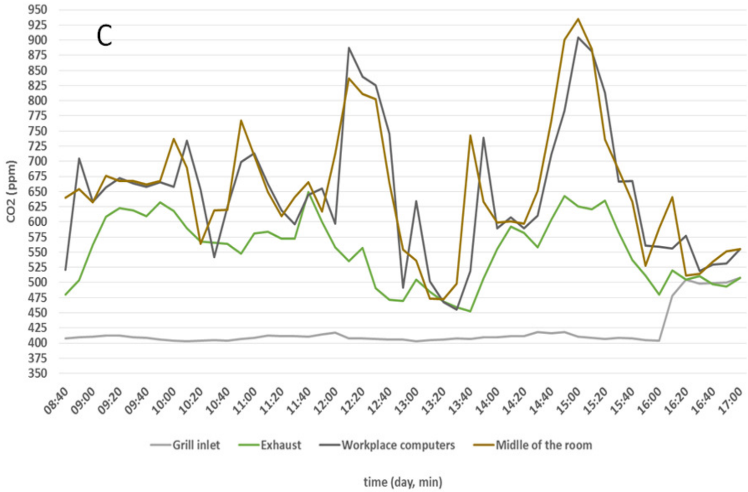

Fig. 4 CO_2 levels learning squares over a period of a working day recorded in school A-D .

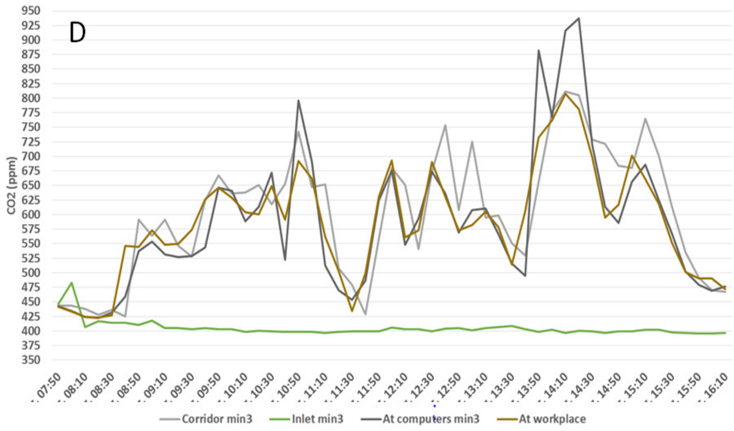

Fig. 5 CO_2 levels learning squares over a period of a working day recorded in school D .

The hygrothermal performance of the learning square was evaluated by the continuous measurement of temperature and relative humidity inside the learning squares, see Fig. 6. From these the PMV values were derived, see Fig, 7 and 8.

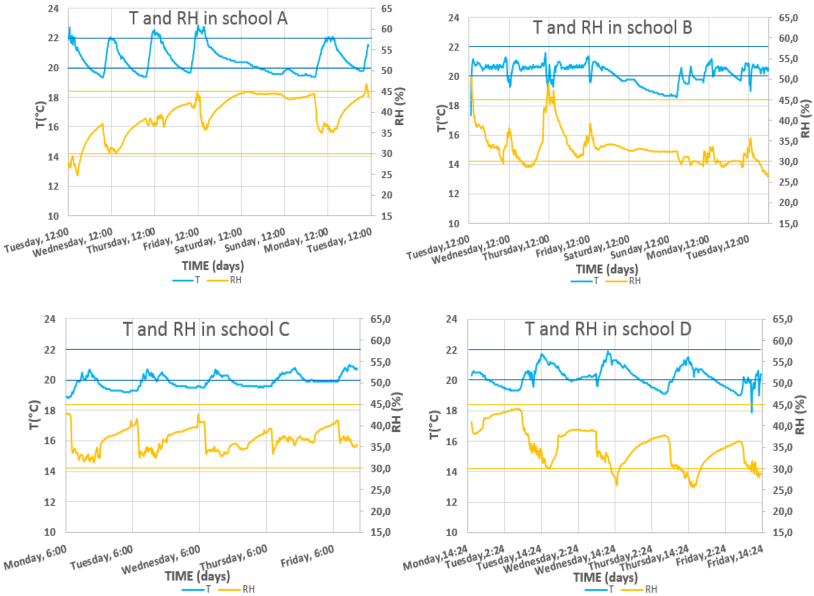

Fig. 6 Temperature and relative humidity in the four learning squares of achool A-D

Fig. 7 PMV in four learning square school A and B

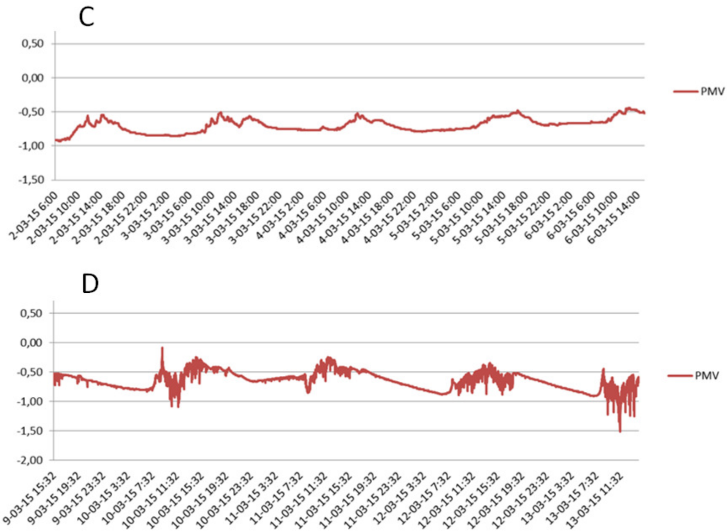

Fig. 8 PMV in four learning square school C and D

Based on EN-15251, PMV ranges from -1.54 to -0.08, indicating a satisfying thermal comfort of learning square is assured during measuring period. Table 4 gives the average temperatures and PMV/PPD values of all four measured schools.

Table 4 Overviw resulting PMV and PPD values

School	Average temperature (°C)	PMV	PPD (%)
A	22	-0.5	13
B	20	-0.5	13
C	19.5	-0.6	14
D	20	-0.6	15

4. Discussion and Conclusions

The learning square is a functional extension of the classroom space for groups or personal activities, and can provide airy space linking the internal and external environments. Measurements were conducted during heating season in four mechanically ventilated new built primary schools in the Netherlands. The four newly built schools are all designed to be class B, which values is between 800 ppm and 1000 ppm over 95% of the weekly school time. Values of CO2 concentration obtained by the measurements achieved the requirement of class A that is less than 800 ppm over 95% of the weekly school time. Temperature and relative humidity meet class B, indicating that all of the examined learning squares are successful to provide the designed air-quality and thermal environment. Our study focused on common area as learning square, and found the CO_2 level during 95% of weekly school time is below 800ppm, and the value of 1200 ppm was not exceeded at any measuring time, except for school A on Friday morning. The well operated ventilation may accounts for the main reason. Those results also demonstrate that through upgrading or installing balanced ventilation system may achieve expected IAQ and thermal comfort. Few other limitations of the present work can be listed but they do not essentially invalidate the main conclusions.

CO_2 concentrations in occupied time is generally below 800ppm, while in unoccupied time it maintains at 400ppm. Based on all the measured four fresh schools have CO_2 concentrations, during 95% of weekly school hours less than 800ppm, which implies very good IAQ were reached in the learning square.

Aside from occupant, CO_2 level in a room also depends on: occupant activity, occupancy schedule, and the adjacent rooms. It has to be noted that air may enter the learning square directly from neighbouring zones, as classroom. CO_2 concentration in classroom, in general, is higher than learning square, in which the CO_2 concentration was affected neighbouring rooms through air flows. As the opening of doors was not filled in by teachers, it is not possible to be completely sure about the fluctuations of CO_2 concentrations in these learning squares are related either to a change in the number of pupils in attendance or the adjacent zones.

Present results and approach can be used as the basis for rational application of balanced ventilation systems that ensure adequate IAQ and thermal comfort of learning square. Future studies could consider investigating correlation between CO_2 concentration and activities and behaviour of the pupils during their stay in school, their age, and also necessity of developing the management strategy for the ventilation control.

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