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Self-reported health and comfort of school children in 54 classrooms of 21 Dutch school buildings

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ABSTRACT

Background: While the indoor environmental quality of classrooms is a potential issue because it may affect the wellbeing of school children, the relations are still poorly studied. This study aimed to investigate the relations between classroom characteristics and health and comfort of school children.

Material and methods: A questionnaire was distributed among 1311 school children (8–12 years old, average 10) of 54 classrooms at 21 schools in The Netherlands. Additionally, the survey included an inspection of the school and its installations and an inspection of the classrooms surveyed using checklists, and monitoring of some environmental parameters (temperature, relative humidity and CO_2 concentration) in the classrooms.

Results: Among the children studied, 87% was bothered by noise, 63% by smells, 42% by sunlight when shining, 35% didn't like the temperature in the classroom (too cold or too warm) and 34% experienced temperature changes. Main diseases reported comprised of allergies (26%), rhinitis (17%), hay fever (16%) and eczema (16%). Health and comfort in non-traditional schools was better than in the traditional schools studied (A non-traditional school is a school in which the way of educating children is different from the traditional way of education, according to a different educational theory). Physical building characteristics of the classrooms studied in the traditional schools were associated with the Classroom Symptom Index (location of school building, heating system, solar devices hampering opening windows or ventilation) and the Classroom Comfort Index (ventilation type, window frame colour, floor material and vacuum cleaning frequency).

Conclusions: Measures to improve acoustical, air, and thermal conditions of children in classrooms are needed. More research is required on the use of different lighting systems and use of different colours in classrooms.

1. Introduction

The classroom is a place where most children spend more time than any other place but home. It is known that the environmental conditions in a classroom can be unacceptable (poor ventilation, noise, inadequate heating or lighting), affecting health, comfort and performance of children. Many studies all over the world have been performed to document the indoor environment in classrooms and to examine its relations with diseases, disorders and learning ability [1].

Several cross-sectional European studies [2–5] have mainly investigated indoor air quality and health of school children. In the US, several studies explored the relation between ventilation rate and attendance rates and student performance (for example in Refs. [6–8]). And at national level (for example in Sweden [9], the Netherlands [10], the UK [11], Greece [12], Finland [13], Denmark [14], Portugal [15], Australia [16], Japan [17] and in China [18]), health effects were assessed by using self-administered questionnaires (in a few also medical examination, performance tests or absence ratings), combined with indoor environmental monitoring of several air pollutant concentrations, inspection of buildings with the use of a checklist and/or several physical measurements (e.g. temperature and relative humidity). Those studies identified a number of problems related to the indoor environment in classrooms, that are likely to have an effect on health.

Studies with a focus on the effect of classroom temperature on thermal sensations of pupils, go back to the 1960s [19]. More recently studies focused on thermal quality, sensation and performance have been performed in Japan [20], Italy [21], Taiwan [22], Iran [23], The Netherlands [24], Denmark [25], US [26], and very recently, in Australia [27]. The 2850 Australian school children taking part in the latter study, preferred lower temperatures than one would expect according to the current applied thermal comfort models.

Studies focused on external noise, such as aircraft, train and traffic noise and performance of school children, were performed from the early 70s and onwards (for example in the US [28], in Germany [29], in Sweden [30] and the UK [31]). While studies on internal noise, mainly from children themselves, started more recently (for example [32]).

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From the studies performed, it is clear that noise (external or internal) influences the performance of school children.

Research on lighting has focused on issues related to insufficient daylight in relation to performance and health (for example [33,34]), too much daylight in relation to glare and overheating [35], and choice of colours (for example [36,37]).

From a literature study [1] performed on the role of the indoor school environment on health, comfort and performance of children in classrooms, it was concluded that most studies performed focused on relations with indoor air quality parameters; studies on classrooms acoustics, noise level, lighting and thermal aspects, have been limited compared to air quality aspects. With all the knowledge gathered it is possible to present a list of factors that have shown to have an effect, as is shown by the recent introduced guidelines for healthy indoor environments within schools [38,39]. Nevertheless, problems are still there, even though the guidelines are met, it still is difficult to make strong conclusions. This is firstly due to the fact that these guidelines are based on criteria that are originally set up for adults, and secondly because they focus on single factors, which do not consider interactions between them. For example, the SINPHONIE guidelines [38] focus mainly on air quality aspects; and the 'Programma van eisen Frisse scholen' ('Programme of demands for Fresh schools') in the Netherlands [39] provides dose-related criteria for each of the factors separately.

It is a fact that only few attempts have been made to perform a holistic analysis of classrooms and student wellbeing (for example [40,41]). Acknowledging the fact that children might respond differently than adults, it was recommended to focus next generation research on customization, i.e. the individual child in a classroom, taking into account next generation pupils and teachers, new ways of teaching, and new technologies [1].

To gain more insights into the current and potential role of indoor environmental factors on health, comfort and performance of children, there is a need for a holistic analysis of classrooms and student health and comfort, in real-life and in experimental, quasi-experimental situations, including classrooms with different space and systems configurations (e.g. heating, lighting, ventilation, educational setting and interior furnishings), environmental factors and other aspects (e.g. confounders), in order to identify associations between environmental characteristics and health and comfort of children.

For this holistic analysis, an investigation was planned, comprising of a field study and a series of laboratory studies:

- Field studies to get an idea of the situation in primary schools in the Netherlands, more specifically to ask children themselves what they experience and need in classrooms to feel and perform well.
- Lab studies to study the effects of different situations in a classroom at the level of the individual child and at group level.

This paper describes the study design and the first descriptive results of the field investigation performed in 21 schools comprising of a questionnaire among 1311 children and a detailed inspection of the 54 classrooms surveyed and the building. Additionally, in 37 classrooms, temperature (T), relative humidity (RH) and carbon dioxide (CO_2) were measured, and a teachers' questionnaire was distributed to the teachers of 54 classrooms to collect information on the actions they perform to adjust the temperature, the light and visual comfort, and noise. The results of the teachers' questionnaire are not reported here.

2. Method

2.1. Study design

In the spring of 2017, 54 classrooms in 21 schools in the Netherlands were visited for a survey on the health and comfort of school children of group 6 and 7 (and in some cases also group 5 and/or 8), in relation to their stay in the classrooms.

2.2. Selection of the schools

The recruitment of schools was on a voluntary basis. For the selection, schools in several regions (North, South, West and East) of the Netherlands were approached directly or via school corporations (that manage a number of schools in a town or region), first by e-mail (and a reminder), and then called on the phone. From November 2016 to May 2017, more than 400 schools were approached. This resulted finally in 25 schools that wanted to participate, of which four cancelled the survey after they were already planned to be visited. From the 21 schools (54 classrooms) studied, 17 schools (40 classrooms) studied had a traditional education system, incl. 2 schools (5 classrooms) from a special traditional school (children with Attention Deficit (Hyperactivitiy) Disorder (AD(H)D), etc.), and 5 schools (9 classrooms) had a non-traditional education system (following the education theory of Jena, Montessori or Dalton). A non-traditional school is defined here as a school at which the way of educating children is different from the traditional way of education, according to a different educational theory. The fundamental difference is that the non-traditional approach allows children more flexibility to do work on their own and at their own pace, while traditional approaches in general engage everyone in the same activity at the same time.

2.3. Survey

The survey of the schools comprised of a questionnaire for the children, a questionnaire for the teacher, an inspection of the school and its installations, and an inspection of the classrooms surveyed using checklists, and monitoring of some environmental parameters in the classrooms (T, RH and CO_2), while the children were filling in the questionnaire.

The schools were visited either in the morning or the afternoon. One team (of one or two researchers) performed the inspection and filled in the building checklist together with the director and/or school assistant, while another team (of two researchers) distributed the questionnaires in the classrooms (including giving an introduction on the background of the survey and answering questions from the children), filled in the classroom checklist and installed the monitoring equipment for CO_2, T and RH. In case that more than two classrooms were visited in one school, six members composed the research team to make it possible to perform the classroom part in two classrooms simultaneously.

2.4. Building checklist

The checklist applied in the former European projects SINPHONIE and OFFICAIR was the basis of the checklists [5,42], with some additions and corrections, since SINPHONIE focused primarily on air quality and OFFICAIR was meant for office workers (adults).

The building checklist included items about the indoor and built environment through characteristics of building, systems and rooms (e.g. operable or no windows, type of HVAC system, lighting system, control system, etc.), characteristics of the built environment (e.g. busy road, rural/surroundings, etc.), processes to maintain and operate the building and activities within it (e.g. cleaning activities/schedule, renovation and retrofitting activities, and maintenance of HVAC system).

2.5. Classroom checklist

The classroom checklist included items about number of occupants (children, teachers), location of classroom in building and dimensions of classroom, items concerned with indoor characteristics (window frames, window operable or not, glazing, lighting, solar screens, reflection on desk, surfaces of ceiling, floor and walls, sources of noise), items about humidity (visible mould growth, dampness, cracks, condensation on windows), items about indoor climate (heating, natural

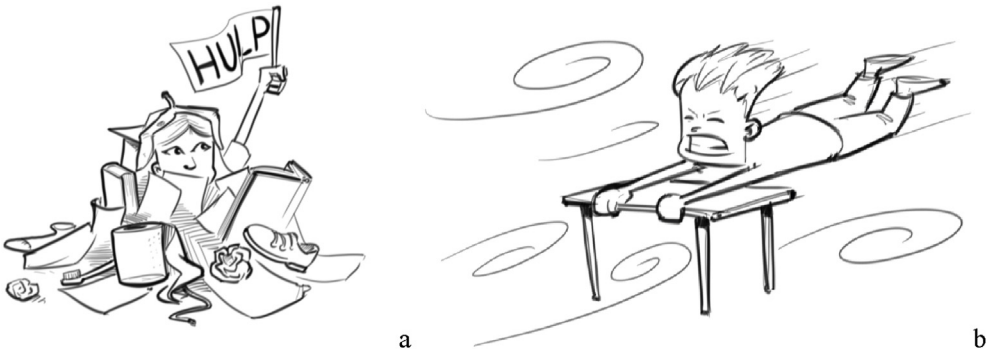

Fig. 1. Drawings were added to the children's questionnaire to make in more attractive and better understandable, for example: a. cleanliness (garbage) of floor; b. draught in classroom.

and/or mechanical ventilation), and indoor pollution sources (board, electronic equipment, furniture materials, fleecy surfaces, paints/chemicals, animals, plants).

2.6. Questionnaire for children

The children's questionnaire, based on the questionnaires applied in SINPHONIE [5] and on a study performed by de Giuli [43], with some parts removed and others added, was developed for children with an age of 9–11 years old (groups 6 and 7). It included general questions (age, sex, commuting, general feeling, location in classroom), questions about health (diseases such as asthma, symptoms such as dry eyes), questions about the classroom (set-up, cleanliness, temperature, draught, smell, noise, visibility, light), and some questions about the house they live in (type of house, location, flooring material in bedroom, smoking at home, pets).

The questionnaire contained special drawings to make it more attractive and interesting for the children, and better understandable in some cases (see Fig. 1). Before administering the questionnaire in the field study, it was distributed among a number of children from the staff, in order to improve and adapt it with the comments.

During the survey, before the questionnaire was distributed, an explanation was given of the contents and purpose of the questionnaire, after which the questionnaires were distributed. In general, it took the children 30 min to fill in the questionnaire, with exceptions of 10–40 min. In some schools, the management wanted also to have group 5 and/or 8 included. Children from group 8 were in general much faster than group 5 and hardly asked any questions.

2.7. Measurements of indoor environmental parameters

In 37 classrooms, CO_2, temperature and relative humidity were measured for approximately 30 min during occupancy of the classrooms (when the questionnaires were being filled in). The CO_2 concentration (ppm), humidity (%) and indoor air temperature (°C) were measured simultaneously by a sensor kit at desk level (Sensirion SHT21 for T and RH; Cozir ambient for CO_2). The resolution (time interval) was 15 s. The sensor kit was connected to a small black box (a connection port) by wireless transmission. A 3G doggle was plugged into the connection port to transmit the data to the server.

2.8. Ethical aspects

After recruitment of the schools, the parents received an information letter and a consent letter from the school management, which usually happened two weeks before the visit. On the day of the survey, the research team collected the consent forms. For the children without permission to fill in the questionnaire, the school management could decide to have them removed from class, and therefore did not fill in the questionnaire, or the filled in questionnaires were destroyed afterwards.

The Ethics committee of the TU Delft gave approval for the study.

2.9. Data management and analysis

All data from the questionnaires and checklists were manually typed in and stored in IBM SPSS Statistics 24.0. For the children's questionnaires, a second person systematically checked the input of the questionnaire data.

Classroom-related symptoms were identified for each classroom, those that improved when away from the school [44], combining these questions: “In the past 3 months, how often did you experience the following symptom?” (never or almost never, every day, sometimes) with “If you marked every day or sometimes, does the symptom becomes less, stays the same or becomes worse at home (away from school)?” (less, the same, worse). If the respondent answered less to the second question, it was considered to be a classroom-related symptom.

Classroom-related symptoms were evaluated by the Building Symptom Index (BSI) based on nine symptoms: dry eyes, itching or watery eyes, blocked or stuffy nose, running nose, sneezing, dry throat, difficulty breathing, dry, irritated or itching skin, and headache. The Classroom Symptom Indexes (CSIs) for each classroom were calculated after assessment of the Personal Symptom Index (PSI) that is, number of symptoms each respondent reported. Every individual index could score any value from 0 to 9, and PSI was missing if all symptoms contributing to the PSI were missing. Then, the PSI values were averaged per classroom to determine the CSI-9 for each classroom.

Classroom-related comfort complaints were evaluated by the Building Comfort Index based on 7 complaints or dissatisfaction ratings: thermal discomfort, temperature changes, wind/draught, smells, noise, sunlight and artificial light. While for temperature changes, sunlight and artificial light, one question was asked (“Are you bothered by temperature changes/sunlight/artificial light?”), noise, smell and draught were preceded with another question: “Is there noise/smell/draught in your classroom?” (Every day, Sometimes, No). If the answer was every day or sometimes: Are you bothered by it? (Yes, Often, Sometimes, No) was asked. For temperature, a 5-point scale was used (‘I am very cold’, ‘I am cold’, ‘It is fine’, ‘I am warm’, ‘I am very warm’). Respondents not answering ‘It is fine’, were taken as being dissatisfied with the temperature. The Classroom Comfort Indexes (CCIs) for each classroom were calculated after assessment of the Personal Comfort Index (PCI) that is, number of comfort complaints reported by each respondent. Each individual could score any value from 0 to 7, and PCI was missing if all symptoms contributing to the PCI were missing. Then, the PCI values were averaged per classroom to determine the CCI-7 for each classroom.

Descriptive statistics such as percentages, range (minimum–maximum), or arithmetic mean with standard deviation (SD)

were used to summarize the characteristics of the school children and their classrooms.

In general, CSI and CCI were distributed in a normal way (Shapiro-Wilk test, P-value = 0.498 and 0.744 for resp. CSI and CCI), but PSI and PCI were distributed in a non-normal way (Shapiro-Wilk test, P-value less than 0.001 for PSI and PCI). Due to a non-normal distribution of CSI and CCI in the sub-group of some classroom characteristics, comparisons of CSI/CCI-values between classroom characteristics as well as PSI/PCI-values between children were based on non-parametric tests: Kruskal-Wallis tests. Correlations among quantitative variables (CSIs, PSIs, classroom characteristics such as surface area) were determined by Pearson's correlation coefficient or Spearman's rank correlation coefficient. The relations between qualitative variables were examined using chi-square tests.

To examine the relations between CSI-9/CCI-7 and classroom characteristics taking into account potential confounders, multiple linear regressions were fitted. Since there was an overall difference found between the children of different school types, non-traditional schools (Jena, Montessori and Dalton) and the traditional schools (incl. special schools) data could not be pooled together for further analyses.

Variables associated with a P-value of less than 0.20 in the bivariate analyses (Mann-Whitney U tests) were included. The full models were reduced by sequential elimination of terms for which P value > 0.20. Collinearity among variables in the model was measured by the variance inflation factor (VIF). Results from linear regressions were summarized by the regression coefficients with their 95% confidence interval (CI 95%).

Spearman's rank, Kruskal-Wallis, Chi-square test or Mann-Whitney U tests examined relations between health and comfort responses and classroom characteristics.

Data were analysed using SPSS version 24.0 (SPSS Inc. Chicago, IL, USA).

3. Results

3.1. Questionnaire for children

Table 1 presents the number of children who participated. Table 2 shows some personal characteristics of the children for all children, children from traditional schools and children from non-traditional schools. Tables 3–5 show respectively, the health symptoms that they reported to have either 'sometimes' or 'every day' 'in the last 3 months', which decrease when the child is away from school, the diseases they are suffering from, and the comfort related complaints about their classroom they pointed out, for all children, children from traditional schools and children from non-traditional schools.

From Table 2, it follows that for all schools, boys and girls are equally distributed. For non-traditional schools, however, the distribution was 42% boys and 58% girls. The average age was 10 years and it took them on average 7 min to get to school. About half of the children go to school by bike and more than one third walks to school. About one fifth wears glasses or lenses, about one third of the children has someone who smokes at home, and around 52% has a dog, a cat, or a rodent as pet. At the moment of filling in the questionnaire, 87% claimed to feel good.

The most prevalent school-related health symptoms were headache (17%), sneezing (15%) and itchy eyes (14%). For non-traditional schools these were headache (14%), sneezing (12%) and blocked nose (11%). The average PSI-9 for all school children was 3.97, while the average CSI-7 per classroom was 4.01 for all schools (see Fig. 2). For the children going to non-traditional schools these values were a PSI-9 of 3.69 and a CSI-7 of 3.64, and for school children of the traditional schools 4.02 and 4.09. The relations between the means of CSI and PSI for traditional and non-traditional schools are presented in Table 6.

For diseases it was asked "Do you have the following disease?" with possible answers 'Yes', 'No', 'In the Past', and 'I don't know'. Only the respondents that gave the answer 'Yes', were included as having the disease. Main diseases reported comprised of allergies (26%), rhinitis (17%), hay fever (16%) and eczema (16%) (Table 4). For children going to the non-traditional schools these values were respectively 28%, 12%, 13% and 13%.

With respect to annoyance or dissatisfaction, it can be seen that 16% (4% non-traditional schools) did not like their classroom ("Do you like your classroom?") (Yes, No) and 16% (8% for non-traditional schools) found the layout of the desks not good ("How is the layout of the desks?") (Good, Not good) (Table 5).

Table 1
Total children per group per school that responded (and total surveyed).

School		Children surveyed (total) per group (total)						Total	Total
no	Date	5	5/6	6	7	7/8	8	Rooms	Children
1	19/04			44 (47)	51 (59)			4	95 (106)
2[a]	20/04		49 (64)					2	49 (64)
3	08/05			17 (18)	17 (19)			2	34 (37)
4	09/05			15 (15)			29 (32)	3	44 (47)
5	09/05			27 (29)	24 (28)			2	51 (57)
6[a]	11/05			25 (28)	30 (30)			2	55 (58)
7	12/05	42 (49)		51 (54)	44 (48)			6	137 (151)
8	16/05			17 (27)	23 (24)	22 (23)		3	62 (74)
9	16/05			40 (45)	40 (53)			4	80 (98)
10	17/05	43 (43)		26 (27)	27 (28)			4	96 (98)
11[a]	19/05			21 (28)	19 (30)			2	40 (58)
12[a]	01/06		19 (20)					1	19 (20)
13	22/05			15 (19)	13 (17)			2	28 (36)
14	23/05			27 (30)	30 (31)			2	57 (61)
15	23/05			28 (28)	20 (21)			2	48 (49)
16	18/05			27 (29)	29 (30)		22 (26)	3	78 (85)
17	12/06			13 (23)	16 (19)			2	29 (42)
18	12/06			32 (32)	21 (23)			2	53 (55)
19[a]	20/06		13 (13)			20 (21)		2	33 (34)
20	20/06		18 (24)			18 (19)		2	36 (43)
21	20/06		6 (23)			15 (15)		2	21 (38)
Total		85 (92)	105 (144)	425 (479)	404 (460)	75 (78)	51 (58)	54	**1145 (1311)**
%		92	73	89	88	96	88		**87**

[a] Non-traditional school (Jena, Montesorri or Dalton).

Table 2
Some personal characteristics of the children.

	All schools			Non-traditional			Traditional			P*
Characteristic	N	n	%	N	n	%	N	n	%	
Personal										
Sex	1145			196			949			**0.008**
- Boy		577	50.4		82	41.8		495	52.2	
- Girl		568	49.6		114	58.2		454	47.8	
Age (mean, sd)	1090	9.99	1.37	183	9.85	1.33	907	10.02	1.38	**0.012**
Wearing glasses or lenses	1136	227	20.0	195	59	30.3	941	168	17.9	**0.000**
Someone smokes at home	1119	352	31.5	193	61	31.6	926	291	31.4	0.961
Has a pet at home (dog, cat or rodent)	1145	602	52.6	196	113	57.7	949	489	51.5	0.118
Transport Method	1137			193			944			**0.000**
- Walking		400	35.2		35	18.1		365	38.7	
- Biking		594	52.2		138	71.5		456	48.3	
- Car		143	12.6		20	10.4		123	13.0	
Transport time in minutes (mean, sd)	1111	6.95	5.19	190	7.99	5.60	921	6.73	5.08	**0.004**
Classroom										
Position 1	918			144			774			**0.000**
- In front		310	33.8		32	22.2		278	35.9	
- In the middle		401	43.7		58	40.3		343	44.3	
- At the back		207	22.5		54	37.5		153	19.8	
Position 2	737			129			608			**0.038**
- Close to window		388	52.6		69	53.5		319	52.5	
- Close to door		261	35.4		37	28.7		224	36.8	
- Close to window and door		88	11.9		23	17.8		65	10.7	
How do you feel at this moment?	1139			194			945			0.270
- Good		993	87.2		176	90.7		817	86.5	
- Not so good		130	11.4		16	8.2		114	12.1	
- Bad		16	1.4		2	1.0		14	1.5	

P*: P-value of Student's t-test or Chi-Square tests between traditional and non-traditional schools. P-values in bold refer to significant relationships at 5% level.

Table 3
Percentage of children that have suffered in the last 3 months, at school, every day and sometimes from symptoms that become less at home (when away from school).

Symptom	All schools			Non-traditional			Traditional			P*
	All %	Girls %	Boys %	All %	Girls %	Boys %	All %	Girls %	Boys %	
Dry eyes	6.7	5.7	7.6	3.1	4.5	1.3	7.4	6.0	8.6	**0.032**
Itchy eyes	14.1	12.8	15.4	9.9	8.1	12.3	15.0	14.0	15.9	0.066
Stuffed nose	10.4	9.9	10.9	11.1	9.3	13.6	10.3	10.1	10.4	0.729
Runny nose	9.3	11.7	7.1	6.8	6.4	7.4	9.9	13.0	7.0	0.193
Sneezing	15.3	15.0	15.6	11.5	10.1	13.4	16.1	16.2	16.0	0.109
Dry throat	11.6	12.9	10.3	9.4	9.1	9.9	12.1	13.8	10.6	0.292
Difficult breathing	5.6	7.3	3.9	4.6	6.2	2.5	5.8	7.6	4.1	0.532
Dry, itchy skin	7.4	8.0	6.8	6.9	7.3	6.3	7.5	8.0	7.0	0.772
Headache	17.0	15.9	18.0	13.5	11.6	16.0	17.7	17.0	18.3	0.154

P*: P-value of Chi-Square tests between traditional and non-traditional schools. P-values in bold refer to significant relationships at 5% level.

Table 4
Percentage of children that are suffering from diseases.

Disease	All schools			Non-traditional			Traditional			P*
	All %	Girls %	Boys %	All %	Girls %	Boys %	All %	Girls %	Boys %	
Asthma	5.7	5.4	6.1	3.7	2.7	5.1	6.2	6.0	6.3	0.180
Bronchitis	1.9	2.0	1.8	2.7	1.8	3.8	1.8	2.0	1.5	0.410
Hay fever	16.0	16.5	15.6	13.4	12.3	15	16.5	17.5	15.6	0.294
Rhinitis	17.4	18.5	16.4	11.8	7.3	17.9	18.6	21.2	16.1	**0.025**
Allergies	26.3	27.2	25.4	28.4	29.7	26.6	25.9	26.6	25.2	0.469
Eczema	16.0	19.9	12.2	13.4	12.8	14.1	16.6	21.7	11.8	0.274
Diabetes	0.6	0.4	0.7	0	0	0	0.7	0.5	0.9	0.263

P*: P-value of Chi-Square tests between traditional and non-traditional schools. P-values in bold refer to significant relationships at 5% level.

87% (81% non-traditional) of the children was bothered by noise, 63% (45% non-traditional) was bothered by smells, 42% (41% non-traditional) by sunlight when shining, 37% (32% non-traditional) by garbage on the floor, 35% (22% non-traditional) did not like the temperature in the classroom (too cold or too warm) and 34% (25% non-traditional) experienced temperature changes.

The average PCI-7 for all school children, for school children from traditional schools and for school children of non-traditional schools was respectively 2.76, 2.87 and 2.24, while the average CCI-7 for all classrooms, traditional classrooms, and classrooms from non-traditional

Table 5
Annoyance/dissatisfaction of children with classroom conditions.

Complaint (dissatisfied)	All schools			Non-traditional			Traditional			P*
	All %	Girls %	Boys %	All %	Girls %	Boys %	All %	Girls %	Boys %	
I do not like the classroom	15.9	16.4	15.3	4.1	1.8	7.3	18.3	20.1	16.7	**0.000**
The layout of the desks is not good	15.8	16.6	15.0	8.2	8.8	7.3	17.4	18.5	16.3	**0.001**
Bothered by garbage on floor	37.0	40.7	33.6	31.6	33.3	29.3	38.3	42.5	34.4	**0.016**
Thermal discomfort at this moment (too warm/cold)	34.9	34.7	35.1	22.4	20.2	25.6	37.5	38.4	36.7	**0.000**
Bothered by temperature changes	34.0	31.4	36.6	25.1	19.3	33.3	35.9	34.5	37.2	**0.004**
bothered by wind/draught	7.3	7.8	6.9	5.7	6.1	5.0	7.7	8.2	7.2	0.529
bothered by smells	62.7	67.0	58.6	45.4	50.9	37.8	66.6	71.1	62.4	**0.019**
bothered by noise	86.6	91.0	82.2	80.8	87.6	71.3	87.8	91.8	84.0	**0.031**
Bothered by sunlight when shining	41.8	43.2	40.4	40.7	45.5	34.1	42.1	42.7	41.5	0.730
Bothered by artificial light when on	11.3	11.3	11.3	6.2	7.1	4.9	12.3	12.4	12.2	**0.014**

P*: P-value of Chi-Square tests between traditional and non-traditional schools. P-values in bold refer to significant relationships at 5% level.

schools was respectively 2.78, 2.89 and 2.20 (see Fig. 3). The relations between the means of CCI and PCI for traditional and non-traditional schools are presented in Table 6.

The most frequently occurring smells in the classroom according to the children of the traditional schools were 'human' (56%) and 'stuffy' (27%) (Fig. 4). For non-traditional schools these values were 41% and 26%, and for all the schools 53% and 27%.

3.2. Some building and classroom characteristics

Table 7 shows some general characteristics of the buildings for all schools studied, while Table A1 (appendix A) presents general characteristics of the building services, as well as aspects of the classrooms studied.

With respect to the location of the schools, 11 schools (26 classrooms) were located in the West of the Netherlands, 7 in the North (18 classrooms), 2 in the South (8 classrooms) and 1 in the East (2 classrooms). From the classrooms studied, 16 were situated in a village in a rural area, 28 in the suburbs and 10 in a city centre. Height varied from 1 to 3 floors above ground level; and the year that the building was in use as a school, ranged from 1927 to 2015.

From Table A1 it can be seen that 18 classrooms (4 non-traditional) studied had mechanical balanced ventilation, 10 (4 non-traditional) mechanical assisted ventilation (exhaust only) and 26 classrooms (1 non-traditional) had natural ventilation only. Of the classrooms with mechanical ventilation (balanced or assisted), 12 (2 non-traditional) were controlled through the CO_2 concentration. All of the mechanical balanced ventilation systems were of the mixing type (no displacement ventilation was observed), and all classrooms had operable windows. 42 (2 non-traditional) classrooms had radiators as a heating system, 12 (2 non-traditional) floor heating, 19 (4 non-traditional) heated air and 15 (4 non-traditional) classrooms had some form of cooling.

Table 6
Bivariate analysis of type of school and CSI/PSI/CCI/PCI.

	n (%)	Mean (s.d.)	P*	Mean (s.d.)	P*
Classroom level	n (%)	CSI-9		CCI-7	
Type of primary school (N = 54)			**0.012**		**< 0.001**
- Traditional	45 (83.3)	4.1 (0.5)		2.9 (0.5)	
- Non-traditional	9 (16.7)	3.6 (0.3)		2.2 (0.4)	
Child level	n (%)	PSI-9		PCI-7	
Type of primary school (N = 1145)			**0.025**		**< 0.001**
- Traditional	949 (82.9)	4.0 (2.1)		2.9 (1.4)	
- Non- traditional	196 (17.1)	3.7 (1.7)		2.2 (1.3)	

P*: P-value of Student's t-test.
P-values in bold refer to significant relationships at 5% level.

Also interesting to mention, is that 6 (2 non-traditional) classrooms had single glazing, and 3 (1 non-traditional) classrooms triple glazing. Solar shading devices were present in most classrooms, while in 29 (5 non-traditional) classrooms these solar devices hampered the use of windows or decreased ventilation. In 18 (1 non-traditional) classrooms, the window frames were dark-coloured with light-coloured walls, and in most classrooms had fluorescent armatures. What is interesting to see is that the colours of the floors had the most variation, whilet walls and ceilings were generally white.

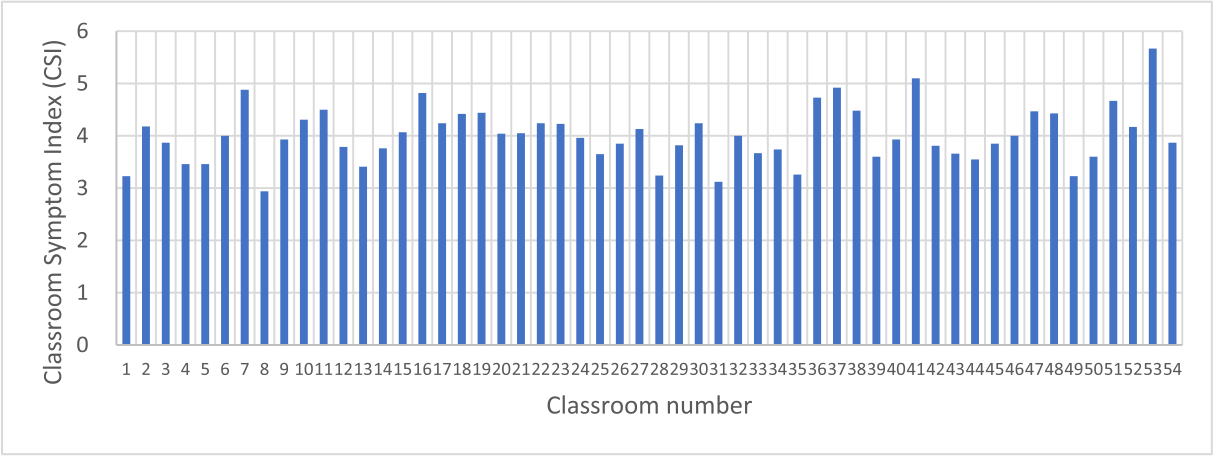

Fig. 2. CSI-9 for each classroom.

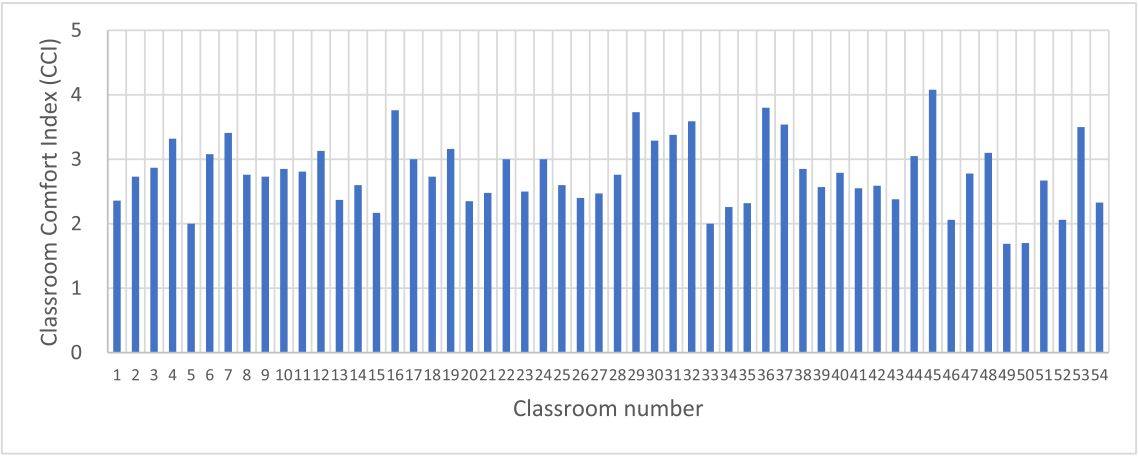

Fig. 3. CCI-7 for each classroom.

In respectively 33 and 39 (7 and 9 non-traditional) classrooms, no potential indoor (except for children present) and outdoor sources of noise could be identified, while sound absorbing ceiling tiles were present in 48 (7 non-traditional) classrooms.

In 52 (9 non-traditional) classrooms, the flooring material was of the synthetic smooth type, while two of them had laminate parquetry. 24 (5 non-traditional) classrooms featured potted plants, 6 (2 non-traditional) curtains, and all classrooms had electronic equipment present. No classrooms had visible mould growth, while in 9 classrooms visible leaks/cracks were noticed and 4 had condensation on the inside of the windows. Cleaning of floors in the classrooms occurred mostly in the afternoon or after school time, in 43 (6 non-traditional) classrooms floors sweeping occurred at least once a week, while vacuum cleaning and/or washing of floors occurred respectively in 26 and 34 (5 and 2 non-traditional) classrooms at least once a week.

3.3. Building characteristics versus health and comfort

To examine the relations between CSI-9/CCI-7PSI-9/PCI-7 and a number of classroom characteristics that could be used as a surrogate for causes of problems (e.g. air pollution sources, noise sources, sources creating thermal and lighting problems, multiple linear regressions were fitted and multivariate analysis was performed.

Due to a strong association with type of primary school (Jena, montessori etc. vs. traditional school) for both CSI/PSI and CCI/PCI (Table 6), but also because of some of the relevant differences found between the personal, health symptoms, diseases and comfort complaints reported by the children of the two clusters of schools (Tables

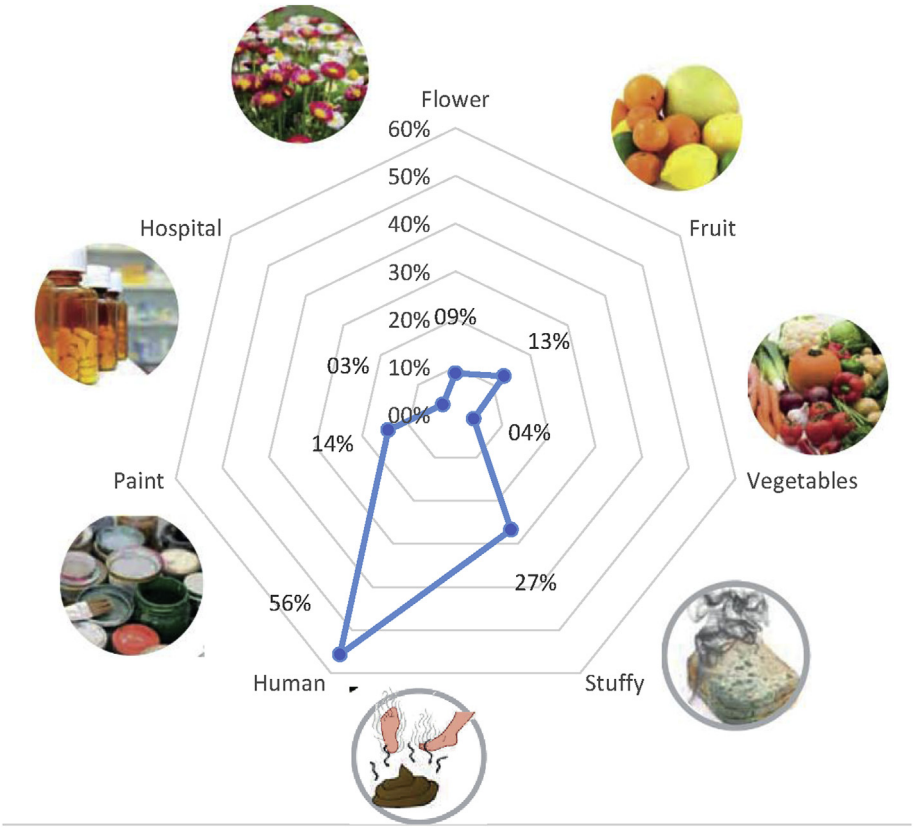

Fig. 4. Type of smells in classroom pointed out by children (excluding the non-traditional schools).

Table 7
General building characteristics.

School number	Location town (region)	Total floor area m^2	Floors above ground	Used as school since	Refurbished in year	No of pupils
1	Gouda (West)	1000	1	1970	–	200
2[a]	Delft (West)	1400	2	1927	2014	240
3	Delft (West)	2200	2	2014	–	140
4	Alkmaar (North)	1636	1	1978	2016	128
5	Alkmaar (North)	1935	3	1927	2005	410
6[a]	Delft (West)	2300	2	1952	2006	276
7	Waalre (South)	1950	1	1965	2014	415
8	Alkmaar (North)	1300	2	1966	2004	276
9	Alkmaar (North)	1500	2	1928	2015	160
10	Barendrecht (West)	920	2	2004	–	285
11[a]	Delft (West)	2100	2	2003	2002	265
12[a]	Delft (West)	1000	2	1992	–	104
13	Den Haag (West)	2200	3	1921	1999	175
14	Den Hoorn (West)	4500	2	2007	2014	240
15	Delft (West)	1200	1	1972	2007	240
16	Rijswijk (West)	1300	1	1986	2015	230
17	Groesbeek (East)	1550	2	2014	–	90
18	Breugel (South)	2000	2	2015	–	308
19[a]	West-Terschelling (North)	1100	2	2015	–	60
20	West Terschelling (North)	1100	2	2015	–	95
21	Midsland (North)	1550	2	1989	2016	86

[a] Non-traditional school (Jena, Montesorri or Dalton).

Table 8
Association between CSI/CCI of children from 45 traditional classrooms and classroom characteristics.

Classroom characteristics	CSI-9	
	Adjusted β ($CI_{95\%}$)	P
Location:		
- Residential area in Suburbs (vs. village in rural area)	−0.37 (−0.74; −0.06)	**0.021**
- City centre (vs. village in rural area)	0.01 (−0.54; 0.57)	0.958
Solar shading devices:		
- No (vs. yes, and not hamper ventilation)	−0.06 (−0.68; 0.47)	0.711
- Yes, and hamper ventilation (vs. yes, and not hamper ventilation)	0.34 (0.05; 0.68)	**0.025**
Lighting type LED and energy saving lamp (vs. Fluorescent)	−0.30 (−1.65; 0.06)	0.068
Classroom characteristics	CCI-7	
	Adjusted β ($CI_{95\%}$)	P
Floor size per child at least 2.3 m^2 (vs. less than 2.3 m^2)	−0.20 (−0.44; 0.05)	0.122
Ventilation type:		
- Mechanical assisted (vs. natural)	0.36 (0.14; 0.87)	**0.008**
- Mechanical balanced (vs. natural)	0.04 (−0.23; 0.32)	0.747

P*: P-value of Student's t-test or ANOVA test of Spearman's rank correlation. P-values in bold refer to significant relationships at 5% level.
CSI-9, Classroom Symptom Index is defined based on 9 symptoms: dry eyes, itching or watery eyes, blocked or stuffy nose, running nose, sneezing, dry throat, difficulty breathing, dry, irritated or itching skin, and headache.
CCI-7, Classroom Comfort Index is defined based on 7 classroom conditions: thermal discomfort, temperature changes, wind/draught, smells, noise, sunlight and artificial light.
β = the estimate of the linear regression coefficient, and CI 95% is the confidence interval at 95%.
All models were adjusted for percentage of children feeling good in the classroom at the time of filling in the questionnaire.
R^2/adjusted R^2 (CSI-9) = 32.4%/21.8%; R^2/adjusted R^2 (CCI-7) = 40.6%/34.7%; Mean variance inflation factor VIF (CSI-9) = 1.322 and mean VIF (CCI-7) = 1.128.

2–5), the bivariate analysis was performed separately for traditional and non-traditional classrooms.

The final multivariate models for PSI-9/CSI-9 and PCI-7/CCI-7 by linear regression were calculated for the traditional classrooms (Tables

Table 9
Association between PSI/PCI from 949 children and classroom characteristics of traditional schools.

Classroom characteristics	PSI-9	
	Adjusted β ($CI_{95\%}$)	P
Location:		
- Residential area in Suburbs (vs. village in rural area)	−0.12 (−0.82; −0.17)	**0.003**
- City centre (vs. village in rural area)	−0.07 (−0.97; 0.03)	0.064
Heating:		
- Radiators below windows (vs. floor heating)	0.12 (0.06; 1.15)	**0.029**
- Heated air present (vs. no)	0.13 (0.12; 1.06)	**0.014**
Solar shading devices:		
- No (vs. yes, and not hamper ventilation)	0.00 (−0.49; 0.46)	0.948
- Yes, and hamper ventilation (vs. yes, and not hamper ventilation)	0.07 (0.00; 0.60)	0.053
	PCI-7	
	Adjusted β ($CI_{95\%}$)	P
Ventilation type:		
- Mechanical assisted (vs. natural)	0.08 (0.05; 0.61)	**0.021**
- Mechanical balanced (vs. natural)	−0.05 (−0.36; 0.06)	0.167
Lighting type LED and energy saving lamp (vs. Fluorescent)	−0.05 (−0.84; 0.12)	0.140
Window frame colour: dark (vs. light)	0.10 (0.10; 0.49)	**0.003**
Room floor material: laminate (vs. synthetic smooth)	0.08 (0.05; 1.02)	**0.031**
Frequency of floor vacuumed: less than once a week (vs. more)	0.09 (0.06; 0.43)	**0.009**

P*: P-value of Student's t-test or ANOVA test of Spearman's rank correlation. P-values in bold refer to significant relationships at 5% level.
PSI-9, Personal Symptom Index is defined based on 9 symptoms: dry eyes, itching or watery eyes, blocked or stuffy nose, running nose, sneezing, dry throat, difficulty breathing, dry, irritated or itching skin, and headache.
PCI-7, Personal Comfort Index is defined based on 7 classroom conditions: thermal discomfort, temperature changes, wind/draught, smells, noise, sunlight and artificial light.
β = the estimate of the linear regression coefficient, and CI 95% is the confidence interval at 95%.
All models were adjusted for percentage of children feeling good in the classroom at the time of filling in the questionnaire.
R^2/adjusted R^2 (PSI-9) = 2.3%/1.6%; R^2/adjusted R^2 (PCI-7) = 3.8%/3.0%; Mean variance inflation factor VIF (PSI-9)1.86 = and mean VIF (PCI-7) = 1.16.

Table 10
Indoor environmental measurements.

School	Group	Classroom no	Max. outdoor air temp.[a] °C	Mean air T (SD) °C	Mean RH[b] %	Mean CO_2 (SD)[c] ppm	Occupancy (children)[d]
3	6	7	15.7	23.1 (0.4)	34	967 (59)	14
4	6	9	13.2	21.9 (0.2)	29	1274 (130)	15
	8	10	13.2	22.1 (0.7)	38	> 2000	16
5	6/7	12	13.2	21.6 (0.8)	34	1833 (176)	24
	6b	13	13.2	22.2 (0.1)	35	> 2000	27
6[e]	6	14	23.4	21.0 (0.3)	32	1204 (94)	26
	7	15	23.4	21.8 (0.7)	33	1248 (126)	30
7	6a	18	23.0	22.5 (0.1)	48	1246 (60)	26
	7a	20	23.0	23.0 (0.3)	46	1188 (107)	23
	7b	21	23.0	23.5 (0.2)	45	1072 (98)	21
8	6	22	25.8	21.0 (1.1)	47	816 (183)	27
	7	24	25.8	24.0 (0.1)	40	641 (31)	24
	7/8	23	25.8	23.8 (0.3)	43	1636 (77)	22
9	6a	25	25.8	23.8 (0.4)	43	679 (51)	22
	6b	26	25.8	24.4 (0.2)	46	> 2000	24
	7a	27	25.8	22.8 (0.2)	47	> 2000	25
	7b	28	25.8	23.0 (0.3)	48	> 2000	27
10	5a	29	29.8	26.2 (0.1)	43	1010 (14)	22
	5b	30	29.8	22.5 (0.7)	51	1121 (122)	21
11[e]	6	33	17.2	21.1 (1.1)	42	1084 (57)	29
	7	34	17.2	22.5 (0.4)	39	1045 (75)	25
12[e]	5/6	35	23.4	24.3 (0.5)	36	1060 (38)	19
13	6	36	24.8	24.4 (0.2)	35	1123 (77)	16
	7	37	24.8	24.3 (0.3)	31	676 (85)	15
14	6	38	19.5	22.6 (0.9)	41	1324 (75)	30
	7	39	19.5	23.6 (0.2)	38	998 (102)	31
15	6	40	19.5	23.2 (0.6)	40	893 (113)	23
	7	41	19.5	23.9 (0.2)	37	667 (40)	28
16	6	42	18.9	23.1 (1.2)	47	1445 (150)	29
	7	43	18.9	24.8 (0.5)	45	1937 (82)	30
18	6	47	19.5	23.4 (0.9)	39	878 (74)	32
	7	48	19.5	25.3 (0.4)	33	707 (39)	21
19[e]	5/6	49	19.0	22.7 (0.7)	53	1086 (69)	13
	7/8	50	19.0	24.0 (0.3)	48	920 (39)	20
20	5/6	51	19.0	23.0 (0.4)	48	776 (73)	18
	7/8	52	19.0	23.7 (0.2)	47	961 (22)	18
21	7/8	54	19.0	21.7 (0.9)	48	682 (74)	15

[a] Outdoor temperature from the weather stations closest to the schools (source: http://projects.knmi.nl/klimatologie/daggegevens/selectie.cgi).
[b] Standard deviation was between 0 and 2%.
[c] Equipment is not able to monitor concentrations above 2000 ppm.
[d] In each classroom 1 teacher +3 researchers should be added.
[e] Non-traditional school (Jena, Montesorri, Dalton).

8 and 9). They were adjusted for percentage feeling 'not so good' and 'bad' today. Because of a too small dataset and too few differences found for the non-traditional classrooms, the multi regression analysis could not be performed.

3.4. Indoor environmental measurements

In Table 10, the environmental measurements in the 37 (4 non-traditional) classrooms are presented. Mean CO_2 concentrations varied from 641 to > 2000 ppm; and 22 of the 37 classrooms monitored had average CO_2 concentrations above 1000 ppm. Mean indoor air temperatures varied from 21 to 26 °C and outdoor air temperatures from cc. 13 to 30 °C. No statistical relevant relationship was found between indoor and outdoor air temperatures or indoor air temperature and the mean relative humidity. The mean relative humidity varied between 29 and 53%.

4. Discussion

4.1. Strengths and limitations

As it can be seen in Table 1, 1145 respondents out of 1311 surveyed children represented a response rate of 87%, which is very high. This is probably due to the distribution procedure that was applied: handing out in person and taking in the questionnaires with an introduction of how to fill in and also with the possibility of asking questions about the meaning of certain questions. The children who were present, but did not fill in the questionnaire, or who did but did not hand it in, were not allowed by their parents (pointed out in the consent form that was sent before the survey and in general returned on the day of the survey).

The study sample was not representative of children between 9 and 11 years old, attending primary schools in general. The selection of schools was on a voluntary basis, which can introduce a potential bias in the results, and the results can therefore not be generalized to the entire primary school-going population.

It should also be mentioned that the fact that both the indoor environmental monitoring as well as the inspection of the classrooms and the schools, were performed during a very short period of time (30–40 min), could be considered a limitation.

However, this study is a first attempt of a holistic analysis of classrooms, in which children could contribute with their own perception and preferences (the outcome of the preferences questions are reported elsewhere together with the teachers questionnaire results). Barett et al. [40] also performed a holistic analysis, but in that study only the teachers were questioned.

4.2. Diseases and health symptoms

The main diseases reported were allergies (26%), rhinitis (17%) and hay fever/eczema (16%). For allergies, it is difficult to compare the

Table 11
Diseases and symptoms reported in some studies at primary schools.

Study	SINPHONIE (Csobod et al., 2014 [5])	Finland (Turunen et al., 2014 [46])	Portugal (Ferreira and Cardoso 2014 [45])	This study (All schools)	Students (Bluyssen et al., 2016c [47])
Number of schools	112 (23 countries)	301	51	21	399
Nr. Classrooms	337	–		54	
Number of children	4919	4248	1019	1145	399
% boy		47.5	51.6	50	47.6
mean age (years)		12.5	6.2 (1st grade) 9.3 (4th grade)	10	22.1
Questionnaire	By parents on paper 2011	Parent + child together digital 3/ 2007–4/2008	Parents on paper 11/ 2010–06/2011	Child On paper April–June '17	Students Digital Spring 2015
Diseases	Past 12 months	Past 12 months		Past 12 months	
Asthma (%)	7.6	8.7	11.8	5.7	6.5
Eczema (%)	16.9	–	–	16.0	18.3
Rhinitis (%)	9.2 nasal allergy	3.6	18.1	17.4	33.2
Allergies (%)	–	–	–	26.3	
Hay fever (%)	–	–	–	16.0	22.0 **OFFICAIR** (Bluyssen et al., 2016d [42])
Symptoms	Past 3 months (not corrected for away school)	Weekly in spring		Past 3 months (become less at home)	Last 4 weeks (become less when away)
Headache (%)	41.1	5.5	8.0	17.0	29
Sneezing (%)	–	–	25.5	15.3	15
Dry eyes (%)	–	–	–	6.7	31
Itchy eyes (%)	13.4	2.1	–	14.1	18
Dry throat (%)	20.6	1.6	–	11.6	20
Stuffy nose (%)	46.6	7.3	–	10.4	14

outcome to other studies performed in primary schools (see Table 11), because the question was not included in that way in those studies. Also, it would be interesting to know what type of allergies the children are referring to, since hay fever is also a form of allergy. Compared to some of the self-reported home characteristics, it can be seen that for the traditional schools there are more children suffering from rhinitis in families with one or more smokers (Table A2 in Appendix A). No relationships could be found for rhinitis or allergies and having a pet at home, or allergies and having a smoker at home.

For rhinitis, the study performed by Ferreira and Cardoso [45] shows almost the same percentage of children suffering, while the SINPHONIE project [5] and the study in Finland [46], found considerably lower percentages of children with rhinitis, which could be due to health outcome definition. In the student homes study of 399 students, 33% was reported [47], positively associated to having relatives with rhinitis, as well as the presence of less than one-year old furniture made of MDF in the bedroom. Both working out and having no pets was negatively linked to rhinitis. Unfortunately, in this study the home environment was not the aim of the investigation, so not enough information on the home environment is available to make such an analysis.

In SINPHONIE [5], parents reported eczema for 17% of their children, and in the students project a percentage of 18 was reported [47], compared to 16% in this study.

5.7% of the children reported to suffer from asthma, boys (6.1%) more than girls (5.4%), but still both in the range of 5–8% for self-reported asthma of children between 11 and 14 years old found in the Dutch epidemiological cohort of 3963 children [48,49]. What is interesting to note, is that the self-reported prevalence of asthma for Dutch students with an average age of 22, was in the same range [47]. Compared to other studies performed at primary schools [5,45,46], the prevalence of asthma was however lower (see Table 11).

While in office buildings, occupants complain mostly about dry eyes (31%) and headaches (29%) [42], the most prevalent school-related health symptoms for all school children were headaches (17%), sneezing (15%) and itchy eyes (14%). Boys reported these symptoms slightly more than girls. Compared to the study performed by Turunen et al. [46], reported percentage of symptoms were considerably higher, while in a study performed by van Dijken et al. [10], no difference was found in prevalence of symptoms at home and at schools. However, it is difficult to compare the self-reported health symptoms from this study to other studies, because of how the questions were formulated (for example in Ref. [5] it was not asked whether the symptoms were decreased when away from school) or because not all of the same symptoms were included in the questionnaire (for example in Ref. [45]).

4.3. Link between health, comfort and classroom characteristics

For the non-traditional classrooms, the bivariate analysis showed that the CSI-9 values differed for location, floor area per child, heating system (floor heating vs radiators below windows), hampering and control of solar shading devices, presence electronic interactive board, time of cleaning floors, floors swept, vacuumed and washed. The PSI-9 values differed for floors swept only.

The CCI-7 values of the non-traditional classrooms differed for location, ventilation principle, heating system (floor heating vs radiators below windows), presence of cooling, control and hampering of shading devices, colour of floor covering and floors swept, and the PCI-7 values for location, heating system (floor heating vs radiators below windows), type of glazing, control and hampering of shading devices, colour floor covering, colour walls, and windows open during cleaning.

Unfortunately, due to a too small dataset for the CSI-9 and CCI-7 and due to too little differences found for the PSI/PCI values among the children of the non-traditional classrooms, no further analysis was performed.

For the 45 traditional classrooms, the bivariate analysis showed that the CSI-9 values differed for location, ventilation principle, presence of heated air, presence of cooling, presence of external solar shading, presence and hampering of solar shading devices, control of solar shading devices, type of lighting, ceiling surface, wall surface and floor surface material and smooth floors washed. The PSI-9 values differed for location, ventilation principle, heating system (floor heating vs radiators below windows), presence of heated air, presence of cooling, presence of external solar shading, presence and hampering of solar shading devices, control of solar shading devices, contrast of window frames, ceiling surface, wall surface and floor surface material.

The CCI-7 values differed between floor area per child, ventilation

principle, presence and hampering of solar shading devices, type of lighting, contrast of window frames, floor surface material and condensation in windows. The PCI-7 values differed for floor area per child, ventilation principle, presence and hampering of solar shading devices, type of lighting, contrast of window frames, wall surface and floor surface material, floors swept and floors vacuumed.

Both the final CSI and PSI model for the 45 classrooms of the 17 traditional schools (Tables 8 and 9) showed that a child at a school in the suburbs has fewer symptoms than a child at a school in a village (in a rural area). Exploring that relation further, in Table A2 (Appendix A) for each of the health symptoms it was analysed whether a relationship with location is present. For children that reported sneezing, stuffy nose, and dry, itchy skin, the relationships seem statistically relevant at both classroom and child level, indicating that children going to school in a village in a rural area, suffer more from sneezing, stuffy nose and dry, itchy skin at school (decreasing when away from school) than children going to school in a residential area of the suburbs. No relationship was found between children with allergies, rhinitis and/or hayfever, and location (Table A2). The cause of this suffering from sneezing, stuffy nose and dry, itchy skin at schools in villages (in rural area), should be investigated further.

It was also seen in the final PSI model that a child in a classroom with radiators below windows has more symptoms than in a classroom with floor heating, or in a classroom with air heating as an important way of heating the classroom. Both findings can indicate the presence of air pollution, either caused by inefficient cleaning or inefficient maintenance of the components of the building services.

For both the final CSI and PSI model, the presence of a solar shading device that hampers ventilation/opening window increased the number of symptoms, which might indicate inefficient ventilation when required.

Both the final CCI and PCI model showed that a child in a classroom with mechanical assisted ventilation has more comfort complaints than in a classroom with natural ventilation.

For the final CCI model it was also seen that when the floor area per child is at least 2.3 m^2, there is a tendency for a child to have fewer complaints.

In the final PCI model, a classroom with a dark coloured window frame vs. a light coloured one increased the PCI, as did laminated flooring vs. synthetic smooth flooring material. Also, vacuuming the classroom floor less than once a week vs. more than once a week increased the PCI. Furthermore, a tendency of an association was found between different types of lighting; fluorescent lighting coming out most negatively. This was also seen in the final CSI model.

4.4. IEQ perception and classroom conditions

Looking into the different IEQ aspects, the self-reported complaints about the classroom conditions showed that noise is the main annoyance to the children, followed by smells, sunlight, garbage on floor, and temperature. Children are bothered the least by draught and artificial light. In the study performed by Turunen et al. [46] in 297 primary schools and 4248 respondents, noise was also the IEQ-related factor reported most frequently, followed by stuffiness/poor air quality.

In general, girls were more bothered by noise, smells and sunlight than boys, while boys were slightly more bothered by temperature differences. For the traditional schools, all complaints were higher than for the non-traditional schools. In a study by Rathunde and Csikszentmihalyi [50] in which the motivation and quality of experience of 290 students from Montesorri and traditional middle schools were compared, also differences were found, indicating a relation with the educational environment.

4.4.1. Acoustical quality

From the 45 traditional classrooms taken into the multivariate analysis, 88% of the children (girls 92% and boys 84%) reported to be bothered by noise (according to them mostly caused by talking of other children in the classroom). From the analysis of 'Bothered by noise' and 'Presence of indoor and/or outdoor sources of noise' (Table A3 Appendix A), it seems that no relationship is present, which confirms the remarks of the children.

According to Shield and Dockrell [51], one of the main effects of noise in the classroom is the reduction of speech intelligibility: one is not able to hear and understand appropriately the teacher or their peers in the classroom which can cause annoyance. Background noise level and reverberation time affect speech intelligibility. Therefore, it is important to keep the background noise level low when someone speaks, as well as having an optimum reverberation time.

In all but two classrooms, the floor was covered with synthetic smooth flooring material (linoleum, marmoleum, vinyl), not contributing very well to the acoustical performance of the classrooms. Also, the walls generally consist of hard surfaces, not particularly good for acoustics, with in some classrooms some wall panels present (to put up drawings). On the other hand, in all but four classrooms, the ceiling surface consists of mineral fiber tiles, meant to be the main measure to improve the indoor acoustical performance of the classrooms.

4.4.2. Air quality

67% of the children is bothered by smells (girls 71% and boys 62%). The most frequently occurring smells in the classroom according to the children are 'human' (56%) and 'stuffy' (27%). Also, from the measurements of CO_2 17 of the 32 (from the 45) classrooms monitored had average concentrations of above 1000 ppm (Table 10), it can be deduced that ventilation of the classrooms in general could be better. Nevertheless, a relationship between air quality responses (bothered by smell) and CO_2 measurements (human indicator) or ventilation type could not be found. Additionally, no relationship was found between hampering shading devices and air quality responses (Table A3).

None of the schools had undergone recent refurbishment. Therefore, it can be assumed that no new furnishing materials were introduced into the classroom. Besides outdoor air, ventilation systems, and the occupants, possible indoor air sources of pollution are: the furniture, potted plants, fleecy material, computers and cleaning activities. No relationship could be found between frequency of cleaning activities and bothered by smell or bothered by smell and complain about stuffy air (as main source of smell) (Table A3).

4.4.3. Thermal quality

With respect to thermal quality, 38% of the children (girls 38% and boys 37%) doesn't like the temperature in the classroom and 36% (girls 35% and boys 37%) is bothered by temperature changes. Only 8% is bothered by draught when it occurs. The indoor air temperature measurements showed a large range (21.0–26.2 °C) (Table 10).

According to de Dear et al. [27], in comparison to adults, children are less sensitive to temperature changes, lose their heat faster, and are more sensitive to changes in their core temperature. Havenith [52] suggested that the differences in metabolic rates of children and adults for typical indoor activities (e.g. sitting-reading-listening-talking) may explain the differences in thermal sensations when exposed to the same temperatures. These findings show the need for thermal comfort guidelines focused on children, and they explain the fact that children are less bothered by thermally uncomfortable conditions to be expected in a classroom (taking current guidelines into consideration).

The relationship found between thermal comfort responses of children and the mean temperature measured was significant at classroom level and child level, as was the relationship between the mean temperature measured and being bothered by draught among those who felt draught in classrooms at classroom level and child level (Table A3). The relationship found between thermal comfort and ventilation type, was significant at child level (Table A3).

Also, the relationship between presence of solar screen devices on the outside and thermal comfort responses (feeling too warm/too cold)

was significant at child level (Table A3), indicating that classrooms with external screens have fewer children feeling thermally dissatisfied.

4.4.4. Lighting quality

While 42% of the children (girls 43% and boys 42%) is bothered by sunlight when it shines, only 12% is bothered by artificial light when it is on.

Only four of the classrooms studied did not have solar screens. Therefore, the complaint related to sunlight could perhaps be related to the type of control of the solar screens, and the interference of closing the solar screens with opening of the windows in relation to the need of fresh air. However, no relationship could be found between bothered by sunlight and control of shading devices or presence of sunlight devices, nor a relationship between bothered by sunlight and hampering of solar devices.

The fact that children complain about the sunlight can also be explained by being bothered directly by the light or because reflection occurs on a surface. In 24% of the classrooms it was seen that the desks have a high reflective surface. However, no relationship was found between bothered by sunlight and reflection of light on surface desk. Also, there was no relationship between dark-coloured window frames and light-coloured walls and bothered by sunlight.

The last option as to why children complain about the sunlight, is that they may feel too warm. Indeed, the relationship found between feeling too warm and being bothered by sunlight was significant at child level.

The colours of floor, ceiling and walls were considered for the comparison of PSI/PCI with classroom characteristics, because studies have shown that preferences for colour might differ per child [36] and that the colour/light combinations of the indoor environmental surfaces might have an effect on perceptual performance of school children [37] and their behaviour and mood [53]. Unfortunately, the questionnaire did not include questions on perception of colours applied in the classrooms. In future studies, this should be taken into account.

5. Conclusions

A first database was created in terms of health and IEQ perception of children at primary schools in the Netherlands as well as the characteristics of the classrooms studied. Among the children studied, 87% were bothered by noise, 63% by smells, 42% by sunlight when shining, 35% didn't like the temperature in the classroom (too cold or too warm) and 34% experienced temperature changes. Main diseases reported were allergies (26%), rhinitis (17%), hay fever (16%) and eczema (16%).

An important finding of the survey of the 54 classrooms, was the differences identified between the children and their self-reported health and comfort complaints going to the non-traditional schools and the other schools (45 classrooms). These differences could be related to the background of the children attending non-traditional schools, but certainly also to the way of teaching, to the time spent in the actual classroom studied, and to the organization of groups and children at these non-traditional schools, that differ from traditional schools. It would be interesting to identify the particular aspects of those educational environments that affect the PSI and PCI of the children that responded to the questionnaire.

With regards to indoor environmental factors the following can be said:

First of all, when one asks children about their school environment, they complain mostly about the acoustical environment. Furthermore, from the findings of the classroom characteristics, it can be concluded that there is an urgent need for acoustical measures. Whether this involves the use of a headphone and/or other acoustical measures, needs to be investigated. Most classrooms have acoustical ceiling tiles, but this is not enough to create the acoustical environment the children need to feel well.

Secondly, from the children's health and comfort responses, the CO_2 measurements, and the multivariate analysis, it is evident that more attention should be paid to (local) source control and to the cleaning of surfaces (specifically floors) and components of building services (such as radiators).

Thirdly, the thermal environment seems very much related to the indoor (air) and outdoor (light) environment of classrooms. The heating and cooling of the classroom is an interplay between sunlight coming in, heating, cooling and air conditioning systems present, solar screens (hampering ventilation or not), operable windows, and the actions of the children and the teachers (opening doors, windows, solar screens, using heat producing equipment, etc.). When having so many persons in one room, it is always difficult to satisfy each one of them. Besides thermal comfort guidelines based on children, there is a need to investigate local control combined with smart integrated design.

Finally, with respect to lighting, whether natural (in combination with solar screens and ways of control in relation to opening windows and other forms of ventilation), or artificial (led lighting and the use of dynamic lighting), but also the use of colours of walls and window frames, seem important topics that have not gotten much attention so far, but could be important for the health and comfort of our children in classrooms.

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Appendix A

Table A.1
Characteristics of the investigated classrooms, for all, traditional and non-traditional schools.

	All	Traditional	Non-traditional
	n (%)	n (%)	n (%)
General building characteristics			
Building location (N = 54/45/9)			
- Village in rural area	16 (29.6)	4 (31.1)	2 (22.2)
- Suburban, residential area	28 (51.9)	25 (55.6)	3 (33.3)
- Urban, city centre	10 (18.5)	6 (13.3)	4 (44.4)
Floor at which classroom (N = 54/45/9)			
- Ground floor	23 (42.6)	22 (48.9)	1 (11.1)
- First floor	28 (51.9)	20 (44.4)	8 (88.9)

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Table A.1 (*continued*)

	All	Traditional	Non-traditional
	n (%)	n (%)	n (%)
- Second floor	2 (3.7)	2 (4.4)	0
- Third floor	1 (1.9)	1 (2.2)	0
Number of children in classroom (N = 54/45/9)	24.3 (4.9)	23.9 (4.5)	26.0 (6.5)
m^2 floor area per child (N = 54/45/9)	2.47 (0.6)	2.5 (0.6)	2.2 (0.6)
Floor area per child (N = 54/45/9)			
- Less than 2.3 m^2	30 (55.5)	23 (51.1)	7 (77.8)
- At least 2.3 m^2	24 (44.5)	22 (48.9)	2 (22.2)
Type of primary school (N = 54/45/9)			
- Non-classical school	9 (16.7)		9 (100)
- Special school (ADHD etc.)	5 (9.3)	5 (11.1)	0
- Classical school	40 (74.1)	40 (88.9)	0
Building services			
Ventilation principle (N = 54/45/9)			
- Natural ventilation only	26 (48.1)	25 (55.6)	1 (11.1)
- Mechanical assisted	10 (18.5)	6 (13.3)	4 (44.4)
- Mechanical balanced ventilation	18 (33.3)	14 (31.1)	4 (44.4)
Position ventilation system intake (N = 18/14/4)			
- Roof	14 (77.8)	10 (71.4)	4 (100.0)
- Façade	4 (22.2)	4 (28.6)	0
Location air supply devices in rooms (N = 18/14/4)			
- High (ceiling or wall)	18 (100%)	14 (100)	4 (100)
Location air exhaust grilles in rooms (N = 28/20/8)			
- High	28 (100.0)	20 (100)	8 (100)
Potential sources close to system intake (N = 18/14/4)			
- None	12 (66.7)	8 (57.1)	4 (100.0)
- Car parking	4 (22.2)	4 (28.6)	0
- Busy road	2 (11.1)	2 (14.3)	0
Replacing air filters (N = 18/14/4)			
- No regular period	4 (22.2)	4 (28.6)	0
- Twice a year or more often	4 (22.2)	2 (14.3)	2 (50.0)
- Once a year	8 (44.4)	6 (42.9)	2 (50.0)
- Less than once every two years	2 (11.1)	2 (14.3)	0
AHU: 100% fresh air present (N = 18/14/4)			
- Yes	18 (100.0)	14 (100)	4 (100.0)
AHU: free cooling system present (N = 18/14/4)			
- No	12 (88.9)	10 (71.4)	2 (50.0)
- Yes	6 (11.1)	4 (28.6)	2 (50.0)
Control mechanical system (N = 28/20/8)			
- Automatic	16 (57.1)	10 (50.0)	6 (75.0)
- CO_2 controlled	12 (42.9)	10 (50.0)	2 (25.0)
Window grill/grid present (N = 54/45/9)			
- No	34 (63.0)	27 (60.0)	7 (77.8)
- Yes	20 (37.0)	18 (40.0)	2 (22.2)
Floor heating present (N = 54/45/9)			
- No	42 (77.8)	35 (77.8)	7 (77.8)
- Yes	12 (22.2)	10 (22.2)	2 (22.2)
Heated air present (N = 54/45/9)			
- No	35 (64.8)	30 (66.7)	5 (55.6)
- Yes	19 (35.2)	15 (33.3)	4 (44.4)
Radiators located below windows (N = 54/45/9)			
- No	12 (22.2)	10 (22.2)	2 (22.2)
- Yes	42 (77.8)	35 (77.8)	7 (77.8)
Cooling of classroom (N = 54/45/9)			
- No	39 (72.2)	34 (75.6)	5 (55.6)
- Yes	15 (27.8)	11 (24.4)	4 (44.4)
Operable windows (N = 54/45/9)			
- Yes	54 (100)	45 (100)	9 (100.0)
Type of glazing (N = 54/45/9)			
- Single glazing	6 (11.1)	4 (8.9)	2 (22.2)

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Table A.1 (*continued*)

	All	Traditional	Non-traditional
	n (%)	n (%)	n (%)
- Double glazing	28 (51.9)	24 (53.3)	4 (44.4)
- Double glazing (with HR)	17 (31.5)	15 (33.3)	2 (22.2)
- Triple glazing	3 (5.6)	2 (4.4)	1 (11.1)
Lighting			
Solar shading devices (N = 54/45/9)			
- None	4 (7.4)	4 (8.9)	0
- External	26 (48.1)	19 (42.2)	7 (77.8)
- Internal	11 (20.4)	11 (24.4)	0
- Both	13 (24.1)	11 (24.4)	2 (22.2)
External shading devices (N = 54/45/9)			
- No	15 (27.8)	15 (33.3)	0
- Yes	39 (72.2)	30 (66.7)	9 (100)
Do solar shading devices hamper use of windows or decrease ventilation (N = 50/41/9)			
- No	21 (42.0)	17 (41.5)	4 (44.4)
- Yes	29 (58.0)	24 (58.5)	5 (55.6)
Control of shading devices (N = 50/45/9)			
- Individual	44 (88.0)	37 (90.2)	7 (77.8)
- Automatic	2 (4.0)	2 (4.9)	0
- Automatic with individual by-pass	4 (8.0)	2 (4.9)	2 (22.2)
Type of artificial lighting (N = 54/45/9)			
- Fluorescent	50 (92.6)	43 (95.5)	7 (77.8)
- LED or energy saving lamp	4 (7.4)	2 (4.4)	2 (22.2)
Reflection of light on surface desk (when light is on) (N = 54/45/9)			
- No	37 (68.5)	6 (66.7)	6 (66.7)
- Yes	17 (31.5)	3 (33.3)	3 (33.3)
Contrast of window frames (N = 54/45/9)			
- Light-coloured window frames with light-coloured wall	36 (66.7)	8 (88.9)	8 (88.9)
- Dark-coloured window frames with light-coloured wall	18 (33.3)	1 (11.1)	1 (11.1)
Acoustics			
Potential indoor sources of noise (N = 54/45/9)			
- None	33 (61.1)	26 (57.8)	7 (77.8)
- Occupants	7 (13.0)	7 (15.6)	0
- Neighbours	8 (14.8)	6 (13.3)	2 (22.2)
- Vibration from fans	5 (9.3)	5 (11.1)	0
- Other	1 (1.9)	1 (2.2)	0
Potential outdoor sources of noise (N = 54/45/9)			
- None	39 (72.2)	30 (66.7)	9 (100.0)
- Traffic	4 (7.4)	4 (8.9)	0
- People	10 (18.5)	10 (22.2)	0
- Other	1 (1.9)	1 (2.2)	0
Coverings, furnishings			
Ceiling surface (N = 54/45/9)			
- Paint	4 (7.4)	4 (8.9)	0
- Sound adsorbing ceiling tiles	48 (88.9)	41 (91.1)	7 (77.8)
- Gypsum/plaster	2 (3.7)	0	2 (22.2)
Wall covering (N = 54/45/9)			
- Paint	43 (79.6)	35 (77.8)	8 (88.9)
- Wallpaper	8 (14.8)	7 (15.6)	1 (11.1)
- Stone/brick	3 (5.6)	3 (6.7)	0
Floor covering (N = 54/45/9)			
- Synthetic smooth (linoleum, vinyl, …)	52 (96.3)	43 (95.6)	9 (100.0)
- Laminate parquetry	2 (3.7)	2 (4.4)	0
Colour floor covering (N = 54/45/9)			
- Red, orange, autumn	6 (11.1)	4 (8.9)	2 (22.2)
- Grey	5 (9.3)	5 (11.1)	0
- Soil, brown, grey	7 (13.0)	5 (11.1)	2 (22.2)
- Brown, orange, sand	11 (20.4)	8 (17.8)	3 (33.3)
- Yellow, sand	2 (3.7)	2 (4.4)	0
- Bright yellow	4 (7.4)	4 (8.9)	0

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Table A.1 (*continued*)

	All	Traditional	Non-traditional
	n (%)	n (%)	n (%)
- Prussian blue	6 (11.1)	6 (13.3)	0
- Green	13 (24.1)	11 (24.4)	2 (22.2)
Colour walls (N = 54/45/9)			
- White	33 (61.1)	28 (62.2)	5 (55.6)
- White with colourful parts	12 (22.2)	10 (22.2)	2 (22.2)
- Light yellow, off white	2 (3.7)	0	2 (22.2)
- White and grey	2 (3.7)	2 (4.4)	0
- Grey	5 (9.3)	5 (11.1)	0
Colour ceiling (N = 54/45/9)			
- White	54 (100)	45 (100)	9 (100.0)
Indoor pollution sources			
Board (N = 54/45/9)			
- Blackboard with chalk	0 (18.5)	6 (13.3)	4 (44.4)
- White board with markers	39 (72.2)	34 (75.6)	5 (55.6)
- Electronic interactive board	52 (96.3)	45 (100)	7 (77.8)
Board- Electronic interactive board (N = 54/45/9)			
- Yes	54 (100)	45 (100)	7 (77.8)
Equipment-computers present (N = 54/45/)			
- Yes	54 (100)	45 (100)	9 (100.0)
Furniture materials (N = 54/45/)			
- Wood	2 (3.7)	2 (4.4)	0
- Plywood	38 (70.4)	29 (64.4)	9 (100.0)
- Plastic laminate or composite	11 (20.4)	11 (24.4)	0
- MDF furniture less than 1 year old	3 (5.6)	3 (6.7)	0
Curtains present (N = 54/45/9)			
- No	48 (88.9)	41 (91.1)	7 (77.8)
- Yes	6 (11.1)	4 (8.9)	2 (22.2)
Potted plants present (N = 54/45/9)			
- No	30 (55.6)	26 (57.8)	4 (44.4)
- Yes	24 (44.4)	19 (42.2)	5 (55.6)
Humidity problems			
Visible mould growth in room (N = 54/45/9)			
- No	54 (100)	45 (100)	9 (100.0)
Visible/leak crack in room (N = 54/45/9)			
- No	45 (83.3)	36 (80.0)	9 (100.0)
- Yes	9 (16.7)	9 (20.0)	
Condensation on windows (N = 54/45/9)			
- No	50 (92.6)	41 (91.0)	9 (100.0)
- Inside windows	4 (7.4)	4 (8.9)	
Cleaning aspects			
When are the floors cleaned (N = 54/45/9)			
- Early in the morning or before school time	2 (3.8)	0	2 (22.2)
- In the afternoon or after school	52 (96.3)	45 (100)	7 (77.8)
Windows open during cleaning (N = 54/45/9)			
- No	39 (72.2)	32 (71.1)	7 (77.8)
- Yes	15 (27.8)	13 (28.9)	2 (22.2)
Floors are swept (N = 54/45/9):			
- At least once a week	43 (79.6)	37 (82.2)	6 (66.7)
- Less than once a week	11 (20.4)	8 (17.8)	3 (33.3)
Floors are vacuumed (N = 54/45/9):			
- At least once a week	26 (48.1)	21 (46.7)	5 (55.6)
- Less than once a week	28 (51.9)	24 (53.3)	4 (44.4)
Smooth floors washed (N = 54/45/9)			
- At least once a week	34 (63.0)	32 (71.1)	2 (22.2)
- Less than once a week	20 (37.0)	13 (28.9)	7 (77.8)
Surfaces dusted (N = 54/45/9)			
- At least once a week	26 (48.1)	26 (57.8)	0
- Less than once a week	28 (51.9)	19 (42.2)	9 (100.0)
Surfaces cleaned (N = 54/45/9)			

(*continued on next page*)

Table A.1 (*continued*)

	All	Traditional	Non-traditional
	n (%)	n (%)	n (%)
- At least once a week	25 (46.3)	25 (55.6)	0
- Less than once a week	29 (53.7)	20 (44.4)	9 (100.0)

Table A.2
Analysis of possible relationships between self-reported diseases/symptoms and classroom characteristics at classroom and child level for the traditional schools.

Relationship analysed	Traditional schools	
	Classroom	Child
	P*	P*
Diseases		
'Children with Allergies' and 'Location'	0.510	0.505
'Children with Rhinitis' and 'Location'	0.268	0.436
'Children with Hay fever' and 'Location'	0.179	0.286
'Children with Allergies' and 'smoking at home'	0.560	0.375
'Children with Allergies' and 'having a pet at home'	0.750	0.923
'Children with rhinitis' and 'smoking at home'	0.913	**0.016**[a]
'Children with rhinitis' and 'having a pet at home'	0.249	0.635
Symptoms		
'Children with Difficulty breathing' and 'Location'	0.601	0.727
'Children with Headache' and 'Location'	0.884	0.844
'Children with Sneezing' and 'Location'	**0.016**[b]	**0.001**[b]
'Children with Dry eyes' and 'Location'	0.974	0.945
'Children with Itchy eyes' and 'Location'	0.797	0.775
'Children with Dry throat' and 'Location'	0.505	0.696
'Children with Stuffy nose' and 'Location'	**0.001**[c]	< **0.001**[c]
'Children with Runny nose' and 'Location'	0.335	0.150
'Children with Dry, itchy skin' and 'Location'	0.105	**0.025**[d]

P*: P-value of Spearman's rank, Kruskal-Wallis, Chi-square test or Mann-Whitney *U* test.
P-values in bold refer to significant relationships at 5% level.
a: more children suffered from rhinitis in families with smoker.
b: the percentage of children suffering from Stuffy nose is highest in classrooms located in village in rural area, next is urban (city centre), and this percentage is smallest in classrooms located in suburbs.
c: the percentage of children suffering from sneezing is highest in classrooms located in village in rural area, next is urban (city centre), and this percentage is smallest in classrooms located in suburbs.
d: The percentage of children suffered from dry itchy skin is highest in urban, next is suburban, and this percentage is smallest in village.

Table A.3
Analysis of possible relationships between comfort responses and classroom characteristics at classroom and child level for traditional schools.

Relationship analysed	Traditional schools	
	Classroom	Child
	P*	P*
Acoustical quality		
'Bothered by noise' and 'Ventilation type'	0.815	0.497
'Bothered by noise' and 'Presence of indoor noise sources'	0.505	0.238
'Bothered by noise' and 'Presence of outdoor noise sources'	0.093	0.131
Air quality		
'Bothered by smells' and 'Mean CO_2 level'	0.311	0.995
'Bothered by smells' and 'Ventilation type'	0.786	0.795
'Bothered by smells' and 'Frequency floors swept'	0.193	0.871
'Bothered by smells' and 'Frequency floors vacuumed'	0.278	0.138

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Table A.3 (*continued*)

Relationship analysed	Traditional schools	
	Classroom	Child
	P*	P*
'Bothered by smells' and 'Frequency smooth floors washed'	0.404	0.400
'Bothered by smells' and 'Frequency surfaces dusted'	0.400	0.218
'Bothered by smells' and 'Frequency surfaces cleaned'	0.297	0.088
'Bothered by smells' and 'Hampering shading devices'	0.609	0.967
Thermal comfort		
'Thermal discomfort' and 'Mean temperature'	**0.041**[a]	**0.001**[a]
'Bothered by temperature change' and 'Mean temperature'	0.254	0.159
'Bothered by draught' amd 'Mean temperature'	**0.044**[b]	**0.003**[b]
'Thermal discomfort' and 'Cooling system present'	0.657	0.185
'Bothered by temperature change' and 'Cooling system'	0.364	0.181
'Bothered by draught' and 'Cooling system present'	0.785	0.873
'Thermal discomfort' and 'Ventilation type'	0.439	< **0.001**[c]
'Bothered by temperature change' and 'Ventilation type'	0.963	0.886
'Bothered by draught' and 'Ventilation type'	0.292	0.116
'Thermal discomfort' and 'External solar screen present'	**0.050**[d]	< **0.001**[d]
'Bothered by temperature change' and 'External solar screen present'	0.938	0.841
'Bothered by draught' and 'External solar screen present'	0.551	0.713
Lighting quality		
'Bothered by sunlight' and 'Presence of solar shading'	0.530	0.438
'Bothered by sunlight' and 'Type of solar shading control'	0.347	0.725
'Bothered by sunlight' and 'Hampering of solar shading'	0.760	0.699
'Bothered by sunlight' and 'Reflection on desk'	0.993	0.904
'Bothered by sunlight' and 'Feel warm in classroom'	0.170	**0.015**[e]
'Bothered by sunlight' and 'Window frame colour'	0.993	0.165
'Bothered by artificial light' and 'Type of lighting'	0.327	0.074

P*: P-value of Spearman's rank, Kruskal-Wallis, Chi-square test or Mann-Whitney *U* test.
P-values in bold refer to significant relationships at 5% level.
a: the higher the temperature in classrooms, the more children feel uncomfortable.
b: the higher the temperature in classrooms, the less children feel bothered by draught.
c: compared with natural ventilation, there are more children feel uncomfortable in classrooms with mechanical-assisted ventilation system, and less children feel comfortable in classrooms with mechanical-balanced ventilation system.
d: classroom with external solar screen has less children feel thermally uncomfortable or less children feel uncomfortable in classrooms having an external solar shading.
e: the proportion of children bothered by sunlight is higher among children who felt warm.

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