Contents lists available at ScienceDirect

Building and Environment

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

Philomena M. Bluyssen*, Dadi Zhang, Stanley Kurvers, Marjolein Overtoom, Marco Ortiz-Sanchez

Chair Indoor Environment, Department of Architectural Engineering & Technology, Delft University of Technology, Delft, The Netherlands

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]).

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