Hamburg University of applied Sciences, Hamburg
Faculty of Life Sciences
Department of Health Sciences
Master Public Health

Assessment of Indoor Air Quality in Classrooms and Wellbeing of Teachers in Schools of Hamburg, Germany

Master Thesis

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Acknowledgement

To begin with, I thank the most merciful and compassionate

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Date: **08.08.2018** **Preeti Vishnani**

Place**: Hamburg**

List of Abbreviations

%	percent
°C	degree Celsius
ASR	Ausschuss für Arbeitsstätten
BAuA	Bundesministerium für Arbeit und Soziales
CI	Confidence Interval
CO_2	Carbon dioxide
DGUV	Deutsche Gesetzliche Unfallversicherung e.V.
e.g.	For example
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
N	number
Min	Minimum
Max	Maximum
p	p value
df	degree of freedom
m/s	meter per second
n.d.	not defined
RH	Relative Humidity
PM	Particulate matter
ppm	parts per million
OR	Odds Ratio
VOC	Volatile Organic Compound
WHO	World Health Organisation

Abstract:

Background and aims: Problems such as poor indoor air quality (IAQ) and inadequate ventilation are common in schools. These can cause various health problems in students and teachers and ultimately affect their wellbeing. The present study was conducted to assess the indoor air quality in schools of Hamburg, Germany and the subjective perception of teachers about the indoor air quality in schools and work climate and wellbeing status.

Materials and Method: The indoor air quality parameters such as temperature, air velocity, relative humidity and CO_2 were assessed using a multifunctional device (testo 480) in 21 classrooms in 5 schools of Hamburg from April-July 2017. Noise in the classroom was measured using Sound Level Meter PCE-322A. A questionnaire was developed in German language targeting the school teachers to collect the data regarding the perception of room climate and work climate in the school, and to identify common health complaints among them and their WHO-5 wellbeing index score.

Results: Mean temperature, air velocity, relative humidity and CO_2 levels were 24.7 ± 1.84 °C, 0.09 ± 0.03 m/s, 54.2 ± 69.9 %, 995.12 ± 432.26 ppm, respectively. Often the teachers encountered the indoor air problems such as high and low room temperature, stuffy air, noise due to students, changing room temperature and unpleasant smell. Fatigue followed by hoarseness/cough were the common health complaints among the study respondents. The mean WHO-5 wellbeing index score was 54.19 ± 17.64. Around 39% of the study participants had below normal (0-50) WHO-5 well-being score.

Conclusion: The indoor air quality in the studied classrooms was found to be medium air quality accordance with DIN EN 13779: 2007-09. However, this data complies to spring /summer season and cannot be generalised due to its limitations. Also, further research is needed to assess the well-being status of teachers and the association between the indoor air quality and wellbeing.

Keywords: Indoor Air Quality (IAQ), CO_2, Ventilation, School, Classrooms, Wellbeing

1. Introduction

Globally, outdoor and indoor sources of air pollution are considered as the largest environmental risk to health ("Evolution of WHO air quality guidelines: past, present, and future," n.d.). It has been reported that nowadays people spend more than 80% of their time in buildings and therefore are more exposed to indoor pollutants than outdoor (Lee & Chang, 2000) (Ferreira & Cardoso, 2014) (Vilčeková, Kapalo, Mečiarová, Burdová, & Imreczeová, 2017). Consequently, the indoor pollutants and indoor air quality at workplace and residence have gained the attention of researchers and the public (Lee & Chang, 2000). Indoor Air Quality (IAQ) problems in schools may be even more severe than in other kinds of buildings as in schools, there is higher occupancy and insufficient ventilation, intensified by poor construction and maintenance of school buildings (Pegas et al., 2011). Students and staff can suffer from long-term and short-term health problems due to indoor air pollution and it may also decrease their learning capacity. Therefore, in order to ensure better performance and productivity of students and teachers good indoor air quality (IAQ) is important (Annesi-Maesano et al., 2013) (Yang et al., 2015) (Vilčeková et al., 2017).

The IAQ is affected by factors such as emissions from indoor equipment, human activities, emissions through construction materials of the building, infiltration of outdoor air and ventilation deficiencies (Oliveira, Slezakova, Delerue-Matos, Pereira, & Morais, 2017). Occupation rates and local atmospheric conditions influence the indoor levels of indoor pollutants. Indoor temperature and relative humidity may also contribute to the accumulation of indoor pollutants (Oliveira et al., 2017). Also, IAQ is affected by outdoor pollution from traffic, industrial construction and combustion activities near the building (Heudorf, Neitzert, & Spark, 2009).

A study in Hong Kong found PM_{10} and CO_2 levels as the two most important air quality problems in school (Lee & Chang, 2000). Although, the World Health Organisation has not classified CO2 as a pollutant (Stabile, Dell'Isola, Russi, Massimo, & Buonanno, 2017), the indoor CO_2 concentration is used as an indicator of air quality in buildings and of the effective ventilation in occupied rooms (Shendell et al., 2004) (Zhang, Wargocki, & Lian, 2015) (Vilčeková et al., 2017) (Stabile et al., 2017).

A study reported that an indoor CO_2 concentration which is 1000 ppm higher than outdoor was associated with a decrease in yearly attendance of students (Yang et al., 2015). On the other hand, it has also been reported that adequate ventilation in classrooms may lead to reduced absences, prevent infectious disease transmission and improved health and performances of both students and teachers (Kalimeri et al., 2016).

In Europe, there are 21 million students in primary and secondary schools and almost 4.5 million teachers, representing about the 20% of the entire population (Schibuola, Scarpa, & Tambani, 2016). Studies report that problems such as dampness and mold have been found in 24% of schools in Finland, 20% in the Netherlands, and 40% in Spain. Furthermore, inadequate ventilation has been found in a large proportion of schools in Europe (Finell et al., 2018). The situation of schools in Germany is often unsatisfactory as regards to the structure of the buildings. Problems such as ill-fitting windows, leakiness, and signs of wear and tear on brickwork and roofs, as well as damp damage as a result of plumbing leaks are often seen in older buildings (UBA, 2008).

Headaches, fatigue and poor concentration are the common complaints reported by pupils, parents, and teachers in relation to being in school. Besides, irritations of the upper respiratory tracts and eyes, sinus infections and allergic symptoms can also be related to the time spent in schools (UBA, 2008). Teachers being an important part of the society as they have essential duties in education and qualification, which is necessary for shaping the future of upcoming generations. The predominant complaints found among the school teachers in Germany are exhaustion and fatigue, headaches, tension, sleep and concentration disorders, inner restlessness, and increased irritability. In teaching and education, physical and emotional exhaustion is found in 22% of those in service. Teachers' health has a significant effect on quality of teaching and thereby have repercussions on the students' learning (Scheuch, Haufe, & Seibt, 2015). It has also been reported that poor well-being lowers teachers' belief that they can help and support students with emotional and behavioural problems (Kidger et al., 2016). Studies report that teachers, who comprehend their school's physical environment unsatisfactory, report more negative attitudes and decreased moral for their work and observe more problems in the school's social climate than teachers who comprehend the environment as satisfactory. The poor perceived social climate is associated with decreased wellbeing. (Finell et al., 2018).

Numerous studies have been conducted to assess the indoor air quality of classrooms, in particular, the level of CO_2, perceived IAQ and building-related health symptoms, effect on performances, absenteeism, wellbeing (Shendell et al., 2004) (Mendell & Heath, 2004)

(Fromme et al., 2008) (Rosbach et al., 2013) (Madureira et al., 2015) (Yang et al., 2015) (Zhang et al., 2015) (Finell et al., 2018), but these have only focused on the students/children. Moreover, research on the IAQ of schools has been very limited in Europe (Madureira et al., 2015) (Mainka & Zajusz-Zubek, 2015) (Kalimeri et al., 2016) and Germany (Fromme et al., 2007)(Heudorf et al., 2009). Considering the lack of evidence about the situation, the research question that needs to be answered is what the status of indoor air quality in schools of Hamburg, Germany is, and how teachers perceive the indoor air quality in schools and work climate and their wellbeing status. The present study was designed to address this research question.

2. Background

2.1 Indoor Air Quality (IAQ) in schools

Indoor Air Quality (IAQ) refers to “the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants” (US EPA, 2014), whereas indoor air pollution refers to “chemical, biological and physical contamination of indoor air” (“OECD Glossary of Statistical Terms - Indoor air pollution Definition,” n.d.).
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) define acceptable indoor air quality as “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction” (ANSI-ASHRAE Standard 62.1, 2007)
The main (air) contaminants in schools listed by German Federal Environment Agency are as follows:

1. Increased carbon dioxide resulting from inadequate ventilation and airtight windows.
2. Excessive dampness in the building structure or in the indoor air, causing microbial growth.
3. Emissions from building materials and fittings.
4. Diverse odours in the case of inadequate ventilation.
5. Emissions from cleaning materials.
6. Possible release of dust and fumes in technology and science lessons.
7. Particulate matter arising from discharges from outdoor and indoor (UBA, 2008)

The IAQ problems cause non-specific symptoms rather than clearly defined illnesses. The common symptoms associated with IAQ problems are headache, fatigue, shortness of breath, sinus congestion, cough, sneezing, eye, nose, and throat irritation, skin irritation, dizziness, and nausea. However, environmental stressors like improper lighting, noise, vibration, overcrowding, ergonomic stressors, and job-related psychosocial problems (such as job stress) can cause symptoms similar to those associated with poor air quality (“Factors affecting indoor air quality, n.d.). The relationship between indoor air quality and health effects can be seen in Figure 1.

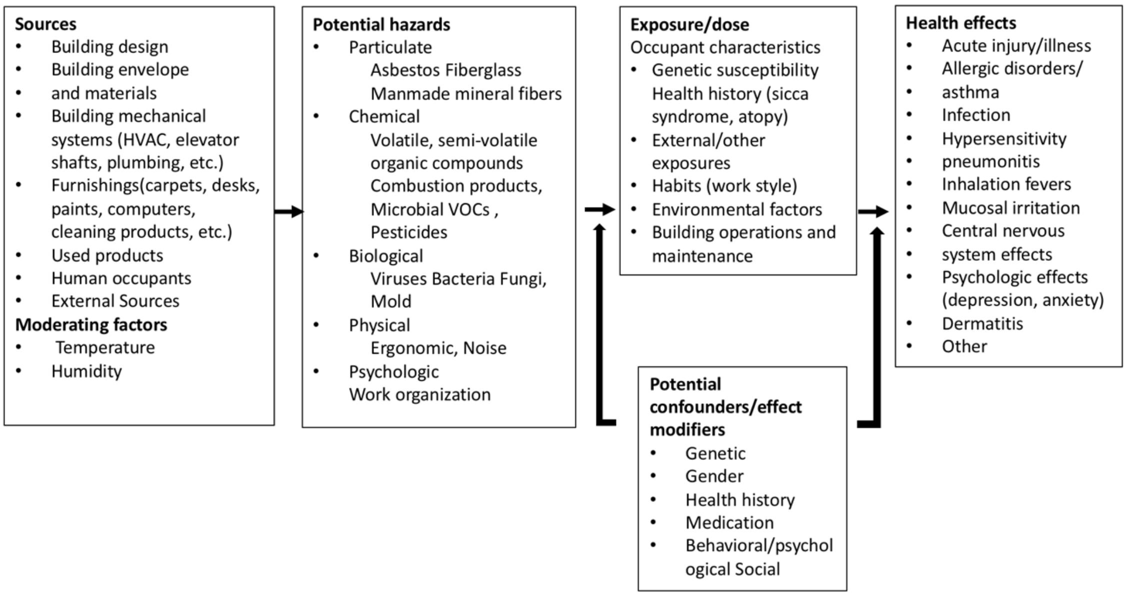


Figure 1: Pathway from IAQ to health effects

Source: (Wu, Jacobs, Mitchell, Miller, & Karol, 2007)

2.2 Ventilation Requirements at School

Ventilation is "the process of exchanging indoor (polluted) air with outdoor (presumably fresh and clean) air" (Wargocki et al., 2002). The main purpose of ventilation is to renew the indoor air by diluting and removing indoor pollutants and to supply fresh air from outside so as to create optimal conditions for humans. It is required to achieve the most comfortable possible air temperature and humidity in the room, as well as thermal balance (Wargocki et al., 2002) (UBA, 2008).

Bio effluent emissions, such as CO_2, moisture, Volatile Organic Compounds (VOCs) and particles from skin, hair, and clothing are generated by building occupants. Building materials also emit VOCs, such as formaldehyde. Nitrogen dioxides, carbon monoxide, benzene and other pollutants. Insufficient ventilation may lead to "air stuffiness", which is associated with increased risk of infection due to the accumulation of viruses and pathogenic bacteria emitted by infected persons, even those without any symptoms of illness. These exposures to physical, chemical and biological factors may be associated with school absenteeism and reduced learning and academic performance ("School environment: Policies and current status," 2015). Furthermore, a few studies have found that increased CO_2 levels, with all other factors constant, adversely affect cognitive performance (Figure 1) (Satish et al., 2012) (Bakó-Biró, Clements-Croome, Kochhar, Awbi, & Williams, 2012)

The key parameter used for assessing air stuffiness in indoor spaces is the concentration of CO_2, the gaseous compound exhaled by humans ("School environment: Policies and current status," 2015). In Germany, a maximum level of 1000 ppm is recommended for classrooms. Table 1 describes the guide values of carbon dioxide concentration in indoor air. (UBA, 2008).

Because of the climatic conditions in Germany, the school buildings have been designed and built in such a manner that natural or fresh air ventilation through windows should be sufficient. For proper airing, the windows should be opened widely (intensive ventilation, cross ventilation) before the school starts and during breaks. Ventilation by tilting the windows is highly ineffective as hardly any air exchange takes place (UBA, 2008).

A pilot research project known as SINPHONIE (Schools Indoor Pollution and Health: Observatory Network in Europe) was done to assess the quality of indoor air in schools and outdoor air in the school vicinity. This multidisciplinary project carried out field surveys in selected schools in 23 countries (maximum of six schools per country). A total of 114 schools participated in the project and in each school, three classrooms were assessed. The mean CO2 levels in all classrooms reported was 1433 ppm. In different geographic regions mean CO2 levels even above 1500 ppm were found. The maximum weekly average CO2 level in a classroom was 4,960 ppm ("School environment: Policies and current status," 2015).

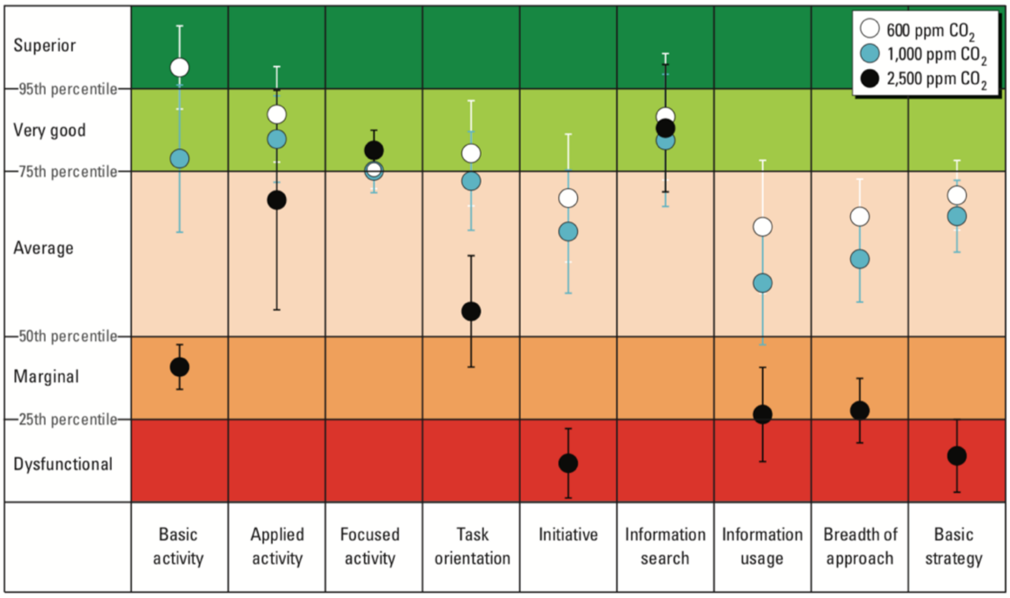


Figure 2: Graph showing Impact of CO2 on human decision-making performance

Source: (Satish et al., 2012)

*Table 1: Guide values for carbon dioxide concentration in indoor air**

CO2 concentration (ppm)	Hygiene rating	Recommendation
<1000	Hygienically insignificant	No further measures
1000-2000	Hygienically evident	• Intensify ventilation measures (increase volume of air flow from outside or air exchange) • Check and improve ventilation
>2000	Hygienically unacceptable	Check ventilation possibilities and if necessary check extensive measures

*Source: UBA (Umweltsbundesamt) (2008)

*Table 2: Classification of indoor air quality in accordance with DIN EN 13779: 2007-09**

Category	Description	Increase in CO2 concentration compared with out- side air [ppm]	Absolute CO2 concentration in indoor air [ppm]	Ventilation rate/ outside air flow volume [l/s/person] ([m3/h/person])
IDA 1	High indoor air quality	≤ 400	≤ 800	> 15 (> 54)
IDA 2	Medium air quality	> 400–600	> 800–1000	> 10–15 (> 36–54)
IDA 3	Moderate indoor air quality	> 600–1000	> 1000–1400	>6–10 (> 22–36)
IDA 4	Poor indoor air quality	> 1000	> 1400	<6 (< 22)

*Source: UBA (Umweltsbundesamt) (2008)

2.3 Optimal Temperature, Relative Humidity (RH), and Air Velocity

The sense of wellbeing is affected by the physical factors such as temperature and relative humidity (“School environment: Policies and current status,” 2015). Both the RH and the room temperature influence the perceived IAQ (Fang, Wyon, Clausen, & Fanger, 2004) (Wolkoff & Kjærgaard, 2007). Extremely low or high temperatures can be associated with poor performance. The region and season determine the optimal temperature range. In Germany, the recommended temperature range for classrooms is between 20°C and 26°C (Fang, Wyon, Clausen, & Fanger, 2004).

As discussed, windows are necessary for adequate ventilation, however, the facing of these windows have an impact on room temperature. If the windows face towards east or west, these can cause excessive heat to build up in the classrooms in summer. South-facing windows are less problematic in this regard (UBA, 2008).

Depending on the time of year, the occupants in school may experience extremely low or high humidity (Angelon-Gaetz, Richardson, Marshall, & Hernandez, 2016). Optimal relative humidity is required for the prevention of moisture accumulation (“School environment: Policies and current status,” 2015). Asthma exacerbation, coughing, wheezing, bronchitis, and upper respiratory infections are associated with indoor dampness (high indoor RH), whereas low RH (“dry air”) may be associated with drying and irritation of skin and mucous membranes, increasing susceptibility to viral infection (Angelon-Gaetz et al., 2016).

The recommended range of relative humidity in general is between 30% and 50% (“School environment: Policies and current status,” 2015). Since relative humidity and temperature are interrelated, Table 1 shows the recommended maximum relative air humidity in relation to air temperature according to the Rule on Workplace Ventilation ASR A3.6 (2012) corresponding to 12g/kg water content.

ANSI/ASHRAE Standard 55-2004 recommends indoor comfort temperatures are 23-26 °C for the Non-Heating Period (NHP) and 20-23 °C for the Heating Period (HP) with an indoor RH of 30-60%.

*Table 3: Maximum relative humidity in relation to air temperature**

Air temperature °C (F)	**Relative Humidity (%)**
20 (68)	80
22 (72)	70
24 (75)	62
26 (79)	55

* Source: (Hellwig & Bux, 2013)

Another important factor that influences IAQ is air movement or air velocity, which is the rate of motion of air in a given direction, expressed in meters per second (m/s). Usually, it has an indirect effect on human health by having both positive and negative effects on other factors such air temperature and relative humidity. For example, still air increases the air temperature and humidity around people thus reducing thermal comfort; contrariwise, moving air if cooler than body temperature can make people feel cooler. If the air velocity is high, it can increase the dryness of skin.

As reported by Federation of European heating, ventilation and air conditioning associations (REHVA), the recommended maximum and minimum values of air velocity range from 0.15 to 0.30 m/s in summer and from 0.15 to 0.25 m/s in winter (Brelih & Seppänen, n.d.). Besides, WHO has set guideline value of 0.25 m/s with regards to air velocity (Abdul-Wahab, Chin Fah En, Elkamel, Ahmadi, & Yetilmezsoy, 2015).

2.4 Noise at Schools

There is no clear physical differentiation between sound and noise. The sound is a sensory perception while noise is an undesired sound. Noise is regarded as any unnecessary disturbance within a useful frequency band. Every human activity is accompanied by noise and it has a negative impact on human well-being. It can be categorised into occupational noise (noise at the workplace and environmental noise) or environmental noise, that includes noise at community, residential, domestic level (e.g. traffic, playgrounds, sports, music) (Concha-Barrientos M, Campbell-Lendrum D, Steenland K; 2004)

Continuous exposure to noise can be a serious threat to the physical and mental health of the population exposed. The direct effect of noise exposure can be hearing impairment or hearing loss; but this effect can be rarely due to environmental noise. Chronic exposure to road traffic noise can lead to decrease in quality of sleep and disturbance of activities or communication, which ultimately leads to Annoyance. Continuous annoyance can cause unspecific physiological stress reactions, by affecting autonomic nervous system and endocrine system (WHO, 2009).

High level of noise is a common problem at school. The teaching and learning process are affected by noise in the school environment (Buchari & Matondang, 2017). In Germany, the noise exposure in schools is regulated by lower and upper action levels, in decibel units using decibel A filters (dB(A)), which imitates the frequency sensitivity of the human ear. 80 dB(A) is the defined lower action level, with recommended measures to reduce measure, whereas, the defined upper action level is 85 dB(A), that triggers mandatory actions to reduce exposure to noise (“School environment: Policies and current status,” 2015). However, the

European Standard EN 15251 recommends 35 dB(A) as maximum noise level in classrooms (Brelih & Seppänen, n.d.).

Poor acoustics in the classroom can negatively affect teaching (UBA, 2008). Shorter reverberation time in Classrooms is needed to understand the speech more clearly. Higher noise levels as a result of increased reverberation time can impair speech understandability and adversely affect the learning process and induce mood disorders ("School environment: Policies and current status," 2015). Proper sound insulation of walls (external and internal), ceilings, roofs, doors and windows against noise (e. g. traffic noise and voices, music etc.), of floors against impact sound (e. g. people walking, including chair movement etc.) and against noise from building services equipment and installations are necessary building acoustic properties (UBA, 2008).

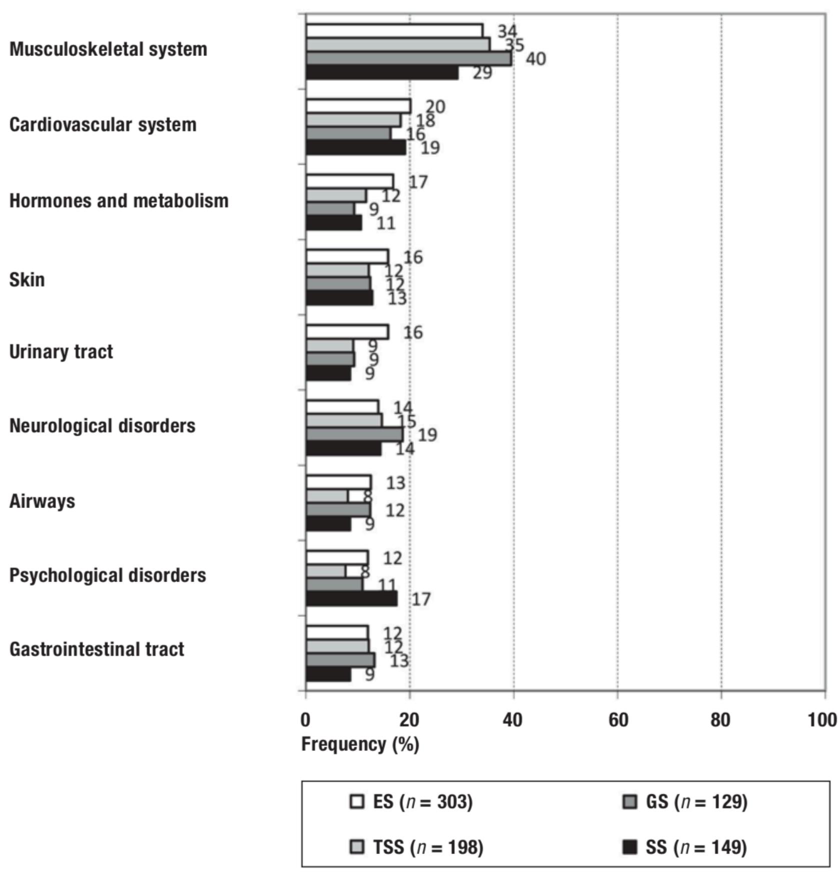
2.5 Health complaints among the school teachers

In the year 2012, teachers constituted 2% of the working population (approximately 5 million people) in the EU. In Germany, there were 797,257 teachers in the 2012/13 school year. Of these, full-time teachers were 498,273, part-time were 298,984, and 148,361 worked on an hourly basis in general and vocational schools (Scheuch et al., 2015).

Teacher occupational wellbeing can be defined as a "positive emotional state resulting from harmony between the sum of specific environmental factors on the one hand, and personal needs and expectations of teachers on the other" (Naghieh, Montgomery, Bonell, Thompson, & Aber, 2015)

The teaching profession is concomitant to high levels of stress and physical complaints, which leads to the poor general wellbeing of teachers. Early retirement and increased level of absenteeism are commonly seen in the teaching job. It has been reported that among school teachers the work-related factors such as high levels of perceived stress, high workload, low collegiality, and low job satisfaction are significantly associated with a lower mental and physical wellbeing (Bogaert, De Martelaer, Deforche, Clarys, & Zinzen, 2014) (Brütting, Druschke, Spitzer, & Seibt, 2017).

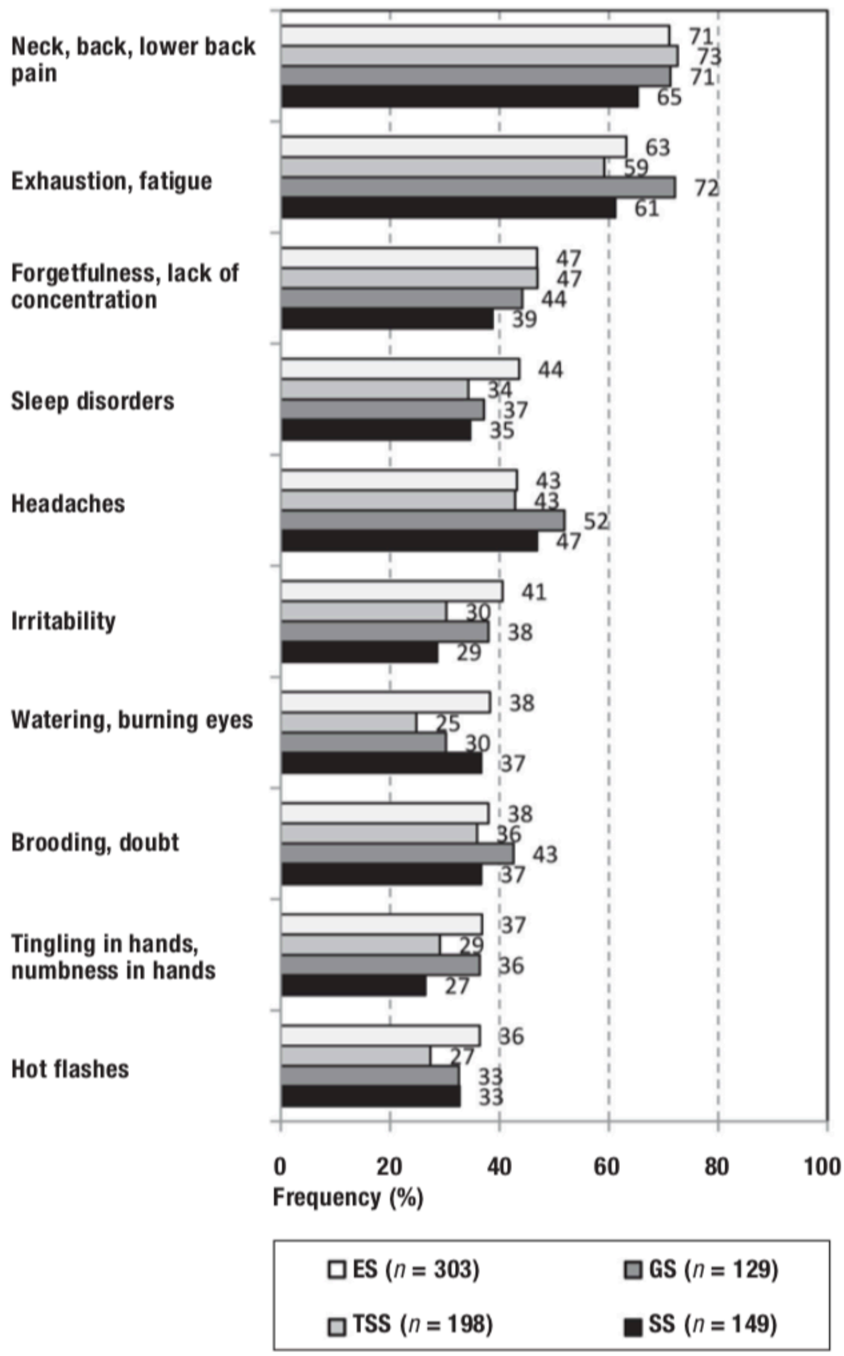
The stress factors in teaching profession can be categorized into (i) Physical factors which include noise and indoor climate factors (ii) Chemical factors, e.g. hazardous substances in specialized teaching and building materials: and (iii) Ergonomic factors, such as computer workstations. Time pressure, prolonged working hours, noise in school, excessively large class sizes, problems with school authorities, lack of autonomy, providing cover for teacher shortages and absences, pressure of school targets and inspections, coping with change and administrative duties, students' behavioural problems and lack of motivation, behaviour problems of parents, and low social status are the stress factors reported by teachers themselves. (Scheuch et al., 2015) (Naghieh et al., 2015). It has been reported that the mental strain among German teachers is much higher than that of employees in other sectors (Zimmermann et al., 2012). In Germany, teachers often complain about the increasing workload (Kieschke & Schaarschmidt, 2008). Prevalence rates of burnout ranging from 1% to 33% among teachers in Germany have been reported (Scheuch et al., 2015).



ES: Elementary School; TSS: Technical Secondary School;
GS: Grammar School; SS: Special School

Figure 3: Graph showing the medical diagnoses of teachers by type of school

Source: (Scheuch et al., 2015)



ES: Elementary School; TSS: Technical Secondary School;
GS: Grammar School; SS: Special School

Figure 4: Graph showing the most common complaints among teachers by type of school

Source: (Scheuch et al., 2015)

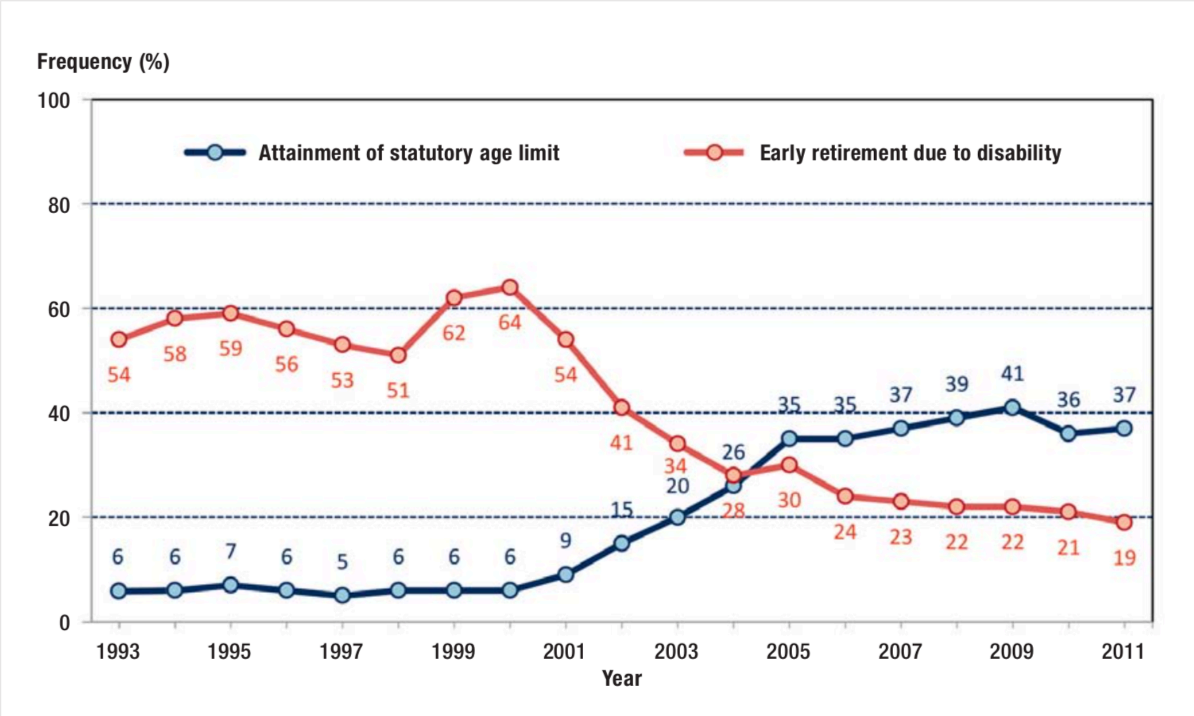


Figure 5: Graph showing the frequency of early retirement due to disability and attainment of statutory age while still fit for work among tenured teachers in Germany between 1992 and 2003

Source: (Scheuch et al., 2015)

2.6 The WHO-5 Wellbeing Index

The World Health Organization Well-Being Index (WHO-5) is a most widely used 5 –item questionnaire for the assessment of subjective psychological well-being. It is a short and generic global rating scale used worldwide. It was first published in 1998, and till now it has been translated into more than 30 languages (Topp, Østergaard, Søndergaard, & Bech, 2015). Since positive well-being is considered to be another term for mental health by the WHO, only positively phrased statements have been included in the WHO-5 (Figure-6). The respondent is supposed to rate how well each of the 5 statements applies to him or her when considering the last 2 weeks. Each item can be scored from 5 (all of the time) to 0 (none of the time). The scores are then added up. The raw score ranges from 0 (absence of wellbeing) to 25 (maximal well-being). Then, it is recommended to multiply the raw scores by 4 to get the final score as per a percentage scale (0- absent; 100-maximal) (Topp et al., 2015)

Because of the adequate validity of the WHO-5 well-being scale, it is widely used as a screening tool for depression and for assessing well-being over time or to compare well-being between groups (Topp et al., 2015).

A report by Eurofound (2017) mentions that the subjective WHO-5 well-being of workers in Europe is quite high- over 65 out of 100 points. The WHO-5 well-being score for workers in Germany is approximately 70 out of 100 (Parent-Thirion et al., 2017).

The WHO-5 questionnaire

Instructions:
Please indicate for each of the 5 statements which is closest to how you have been feeling over the past 2 weeks.

	Over the past 2 weeks...	All of the time	Most of the time	More than half the time	Less than half the time	Some of the time	At no time
1	... I have felt cheerful and in good spirits	5	4	3	2	1	0
2	... I have felt calm and relaxed	5	4	3	2	1	0
3	... I have felt active and vigorous	5	4	3	2	1	0
4	... I woke up feeling fresh and rested	5	4	3	2	1	0
5	... my daily life has been filled with things that interest me	5	4	3	2	1	0

Scoring principle: The raw score ranging from 0 to 25 is multiplied by 4 to give the final score from 0 representing the worst imaginable well-being to 100 representing the best imaginable well-being.

Figure 6: The WHO-5 questionnaire

Source: (Topp et al., 2015)

3. Aims and Objectives

Aims:

1. To assess the indoor air quality in classrooms in the schools of Hamburg, Germany.
2. To assess the wellbeing of school teachers.

Objectives

1. To assess the indoor climate i.e. the levels of carbon dioxide, temperature, relative humidity and air velocity in classrooms in the schools of Hamburg.
2. To assess the level of noise in the classrooms in the schools of Hamburg.
3. To assess the perception of school teachers about the indoor air quality at respective schools in Hamburg.
4. To assess the perception of school teachers about the work climate at respective schools in Hamburg.
5. To assess the WHO – 5 wellbeing index scores of the school teachers in Hamburg, Germany

4. Materials and Method

4.1 Study Design, Setting and Duration

The present study was a cross-sectional survey conducted from April 2017 to July 2017 in 5 different schools in different districts of Hamburg (Figure- 4). The five schools are coded as A, B, C, D and E for the present study.

The study can be divided into two parts. In the first part, the objective measurements of carbon dioxide, temperature, relative humidity and air velocity using testo 480 climate measuring instrument and noise using Sound Level Meter PCE-322A (Figure-) were done in 21 classrooms of the 5 schools. In the second part, the subjective perceptions of teachers with regards to room climate/indoor air quality, work climate and wellbeing was assessed through a questionnaire.

Figure 7: Location of the 5 schools which participated in the study (created using google maps)

Link :
https://www.google.com/maps/placelists/list/16j5UEQ7QXXeK0etfjsfH6FK9NB4?hl=en

4.2 The testo -480 climate measuring device

The testo 480 (Picture 1a) measures climate-related parameters such as temperature, humidity, flow velocity, pressure, and carbon dioxide. The testo 480 is ideally used for measuring comfort level for the evaluation of workplace as well as for flow measurements in and at ventilation and air-conditioning systems (Testo SE & Co. KGaA, 2017).

The testo 480 device has three probes, viz., the 'comfort probe', 'Indoor Air Quality (IAQ) probe' and the 'globe thermometer' (Table 4, Picture 1b). The comfort probe determines air temperature, air velocity and indoor air turbulence in accordance with DIN EN 13779. Turbulence corresponds to the degree of fluctuations in air velocity over time and on the basis of turbulence the draught risk is calculated. The indoor air quality probe measures relative air humidity, carbon dioxide concentration (CO_2), air temperature and absolute pressure (DIN EN ISO 9001). The globe thermometer (thermocouple type K) facilitates the measurement of radiant heat by detecting the significant temperature difference between the ambient and globe temperature. The measurement accuracy for testo 480 corresponds with the recommendations from ASR A3.5 (2010) (Testo SE & Co. KGaA, 2017). The measurements were done with adequate distance during the lectures and with the usual occupancy rate. The measurement of air temperature, air velocity, air humidity and CO_2 were done using a tripod at a height of 0.6 m above the ground.

*Table 4: The study parameters measured by the comfort probe and IAQ probe of testo 480**

	Comfort probe		**Indoor air quality probe**		
Measured parameters	**Air temperature (°C)**	**Air velocity (m/s)**	**Air temperature (°C)**	**Relative humidity (%)**	**CO_2 ppm**
Measuring range	0 to +50 °C	0 to 50 m/s	0 to +50 °C	0 to +100	0 to 10000 ppm
Accuracy	±0.5 °C	±0.03 m/s	±0.5 °C	±1.9%	±105 ppm

*Source: Testo SE & Co. KGaA, 2017

The present study uses the CO2 based measurement to assess the air quality because this method is convenient, inexpensive and reasonably accurate. CO2 is inert and its source of emission i.e. the people are present in all buildings and well dispersed through occupied spaces. It is highly suitable for high occupancy buildings such as schools, where indoor levels can far exceed as compared to outdoor levels (Shendell et al., 2004) (Batterman, 2017).

Even though CO_2 is a proxy indicator of indoor air quality, it is still adopted as sole marker of indoor air quality as per European standards (Stabile et al., 2017). The CO_2 method is appropriate in schools with natural ventilation, mechanical exhaust ventilation and also for full mechanical ventilation systems. Since the natural ventilation depends on the weather, the other measurements such as temperature, wind speed and humidity are also necessary (Methods for monitoring indoor air quality in schools, 2011).

1a

1b

Picture 1a and 1b: Pictures illustrating testo 480 climate measuring device used in the study

4.3 Sound Level Meter PCE-322A

The Sound Level Meter PCE-322A (Picture 2) was used to assess the noise levels in classrooms during the class. A sound level meter is used to assess noise or sound levels by measuring sound pressure. It is also known as a sound pressure level (SPL) meter, decibel (dB) meter, noise meter or noise dosimeter. It uses a microphone to capture sound ("Sound Level Meter / Noise Level Meter | PCE Instruments," n.d.).

This device is specifically designed for noise project; quality control; illness prevention and cure and all kinds of environmental sounds measurement. Since this device is handheld and portable, it can be used to measure sound/noise at factory; school; office; traffic access and household, etc. This unit is in accordance to the IEC61672-1 CLASS2 for Sound Level Meters and provides maximum, minimum and average noise values. ("z-sound-level-meter-pce-322a-en_1045417.pdf," n.d.).

Picture 2: Picture showing the noise measuring device used in the study

4.4 The Questionnaire (Appendix-I)

A 19-itemed self-administered questionnaire in German language was formulated for schoolteachers to assess their subjective perceptions about indoor air quality in the classrooms, work climate and there WHO-5 wellbeing scores. The variables were chosen on the basis of literature research and the MM 040 questionnaire (Andersson, 1998).

The questionnaire was divided into five sections explained below:

First Section

The first section was designed to collect general information of the schoolteachers which included the demographic data such as age group, gender, number of years working as teachers, number of years working in the present school, subjects taught, weekly working hours, numbers of students per class and class levels taught.

Second Section

The second section was formulated to assess the subjective perceptions of schoolteachers with respect to room climate. This section also included the questions related to mechanical ventilation and possibility to open the windows in classroom during lectures.

Third Section

The third section of the questionnaire comprised of questions related to health symptoms and previous medical history as well as smoking habit.

The second and third parts of the questionnaire were based on MM 040 School questionnaire, which is designed to assess indoor climate at schools (Andersson, 1998).

Fourth Section

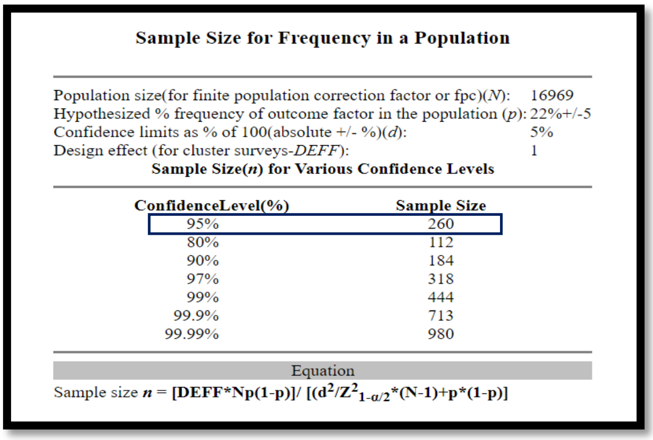
The fourth section of the questionnaire consisted of the WHO-5 Wellbeing Index, German version (WHO, n.d.). The WHO-5 Wellbeing index is a five-itemed global generic scale for measuring wellbeing with 0-5 Likert scaling of each item (Topp et al., 2015).

Fifth Section

The fifth section of the questionnaire dealt with subjective assessment of the working climate in the respective schools.

4.5 Study Population and Sample Size

In Germany there were a total of 758,651 teachers in general education schools in the 2016/2017 school year. In the same year, the number of teachers in Hamburg were 16,969 (Statista, 2017). It has been reported that physical and emotional exhaustion in teaching and education field is 22% (Scheuch et al., 2015). The sample size for the present study was calculated on this basis using the OpenEpi tool Version 3.01 -- Released April 4 and revised April 6, 2013. The required sample size with 95% confidence interval was 260 (Fig-). So, a minimum of 260 filled questionnaires were required to assess the wellbeing of teachers.



Sample Size for Frequency in a Population

Population size(for finite population correction factor or fpc)(*N*): 16969
Hypothesized % frequency of outcome factor in the population (*p*): 22%+/-5
Confidence limits as % of 100(absolute +/- %)(*d*): 5%
Design effect (for cluster surveys-*DEFF*): 1

Sample Size(*n*) for Various Confidence Levels

ConfidenceLevel(%)	Sample Size
95%	260
80%	112
90%	184
97%	318
99%	444
99.9%	713
99.99%	980

Equation

Sample size n = [DEFF*Np(1-p)]/ [($d^2/Z^2_{1-\alpha/2}$*(N-1)+p*(1-p)]

Figure 8: Sample size calculation

Source of calculation: http://www.openepi.com/SampleSize/SSPropor.htm

However, convenience sampling technique was used for the present survey and only 5 schools agreed to participate in the study, out of a total of 41 schools which were approached to participate.

The objective measurements for indoor air quality and noise levels in schools were done in 21 classrooms of the 5 schools that participated in the study. This number was also as per the convenience and time limitation of the schools.

4.6 Pilot Study

Prior to being finalized, the questionnaire was pilot tested on 1 schoolteacher, 2 language schoolteachers and 1 university teacher. A few changes were done in the questionnaire as per the feedback obtained from the pilot study. For example, in the question about the extent of the factors affecting your daily work in the work climate section, the factor "Dealing with integration and inclusion" was added.

4.7 Data Collection

The indoor climate measurements for carbon dioxide, temperature, relative humidity, air velocity and noise were done in 21 classrooms of 5 different schools in Hamburg. The regular lectures at schools in Germany are for 1.5 hours but due to time limitations the measurements were done either in the first 45 minutes or the second 45 minutes of the lecture, depending upon the consent from the respective teachers in the classroom.
The number of people sitting in the classrooms were also noted by the observer. The observer was sometimes allowed to sit inside the class during the measurements and sometimes not, depending on the of convenience teacher in the respective classroom.

The questionnaires were handed over to the coordinating teachers from the respective schools along with a box to drop in the filled questionnaires (Picture 3a and 3b). A total of 206 printed questionnaires were given in the 5 schools. The box with filled questionnaires was collected later from the schools.

4.8 Data Analysis

All the data collected through the instrument and the questionnaire were transferred to IBM SPSS Statistics version 24. The descriptive and analytical statistical tests were performed depending on the type of data (discussed in detail in the results section). The statistical significance level was set at $p<0.05$.

3a

3b

Picture 3a and 3b: Pictures illustrating the box used to collect questionnaires in the study

5. Results

The present study was a cross-sectional survey conducted in 5 schools in 3 different districts of Hamburg, Germany. The objective measurements were done in 21 classrooms of the 5 schools and a total of 206 questionnaires were distributed among the teachers of these schools in order to assess the perceived room and work climate by the teachers.

5.1 Part I: The objective measurements of the indoor air quality and noise in the 5 schools

Table 5 describes the geographic location of the classrooms, number of people (students and teacher and sometimes observer) in the respective classroom, type of ventilation that was used and the time of measurement, i.e. the 1st 45 minutes or the 2nd 45 minutes of the lecture.

Table 5: The number of people. geographic location and the timings of measurements done in the classrooms of the 5 schools in Hamburg

School	Classroom	Number of People	Geographic Location	Measurement during first or second 45 minutes of the lecture	Type of ventilation
A	1	23	West	First	Natural
	2	24	East	Second	Natural
	3	28	North	First	Natural
	4	20	East	Second	Natural
	5	28	West	First	Natural
B	6	16	North	First	Natural
	7	29	South	Second	Natural
	8	29	South	First	Natural
	9	29	North	Second	Natural
	10	25	North	First	Natural
	11	26	South	Second	Natural
C	12	15	South	First	Natural
	13	18	North	Second	Natural
	14	24	North	First	Natural
	15	23	South	Second	Natural
D	16	24	South	First	Natural
	17	25	South	Second	Natural
E	18	25	North	First	HVAC
	19	23	South	Second	HVAC
	20	20	South	Second	HVAC
	21	23	South	First	Natural

The overall mean, minimum and maximum levels of all the 4 variables measured during the study period are described in Table 6. Table 7 outlines the mean values of carbon dioxide, temperature, relative humidity and air velocity in 21 classrooms.

As discussed in the materials and methods, the measurements were done during the first 45 minutes or second 45 minutes, the comparison of the mean values of the measured variables i.e. temperature, relative humidity, air velocity and carbon dioxide in the two time periods are shown in Graphs 1, 2, 3 and 4, respectively.

The differences in temperature, relative humidity, air velocity and carbon dioxide levels with respect to different classrooms are shown in boxplot graphs 5, 6, 7 and 8 respectively. Seeing these boxplots, it can be commented that there is a difference in the levels of measured variables between the classrooms, but the confidence intervals of some classrooms overlap and cover a few other point estimates. Therefore, no dictum about significance can be done. Also, the huge number of outliers can be clearly seen in the boxplot graphs of relative humidity (Graph 6) and air velocity (Graph 7). However, a few outliers can also be seen in the other 2 boxplots of temperature (Graph 5) and CO2 (Graph 8). No statement about statistically significant difference can be given when comparing the measured levels measured during first 45 or second 45 minutes of the lecture because the confidence intervals between these two groups overlap but do not cover the respective point estimates (Graph 9).

Table 6: The mean values of temperature, relative humidity, air velocity and carbon dioxide measured during the study period

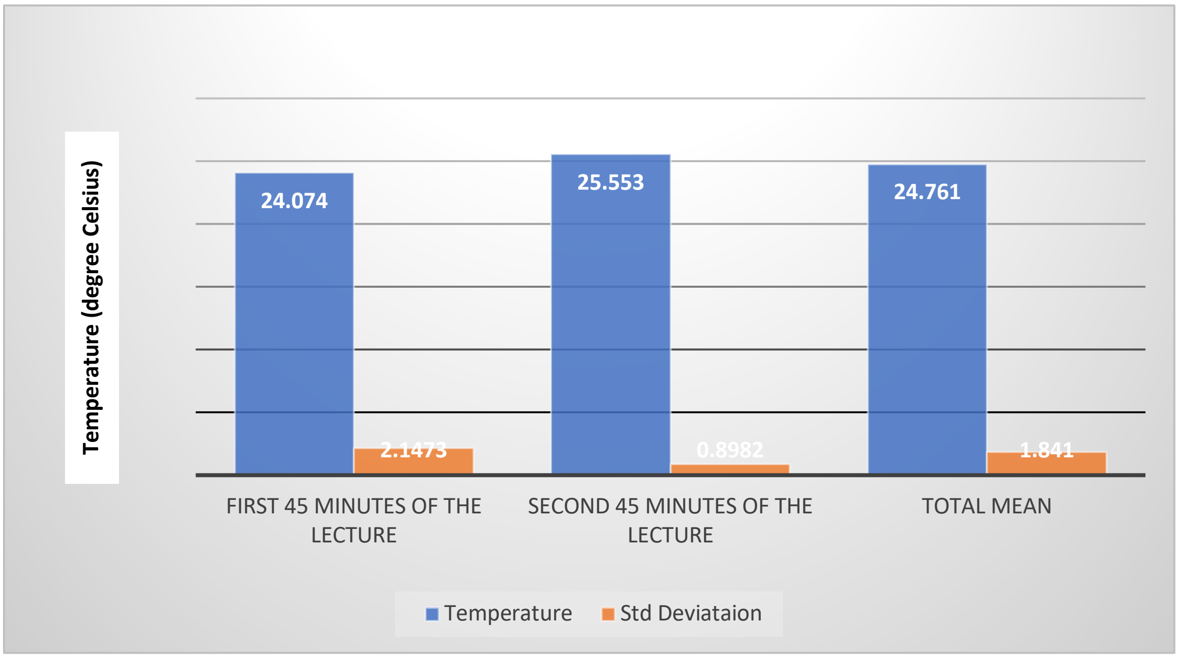
	Mean	**Std. Deviation**	**Minimum**	**Maximum**	**Recommended values***
Temperature (°C)	24.7	1.841	18	27.4	20°C - 26°C [1]
Relative Humidity (%)	54.2	69.926	26.6	69.8	30% - 50% [1]
Air Velocity (m/s)	0.09	0.03977	0.04	0.66	0.15 to 0.30 m/s in summer and 0.15 to 0.25 m/s in winter [2]
Carbon dioxide (ppm)	995.12	432.26	495	2511	1000 [1]

*Sources of recommended values: 1 (“School environment: Policies and current status,” 2015), 2- (Brelih & Seppänen, n.d.)

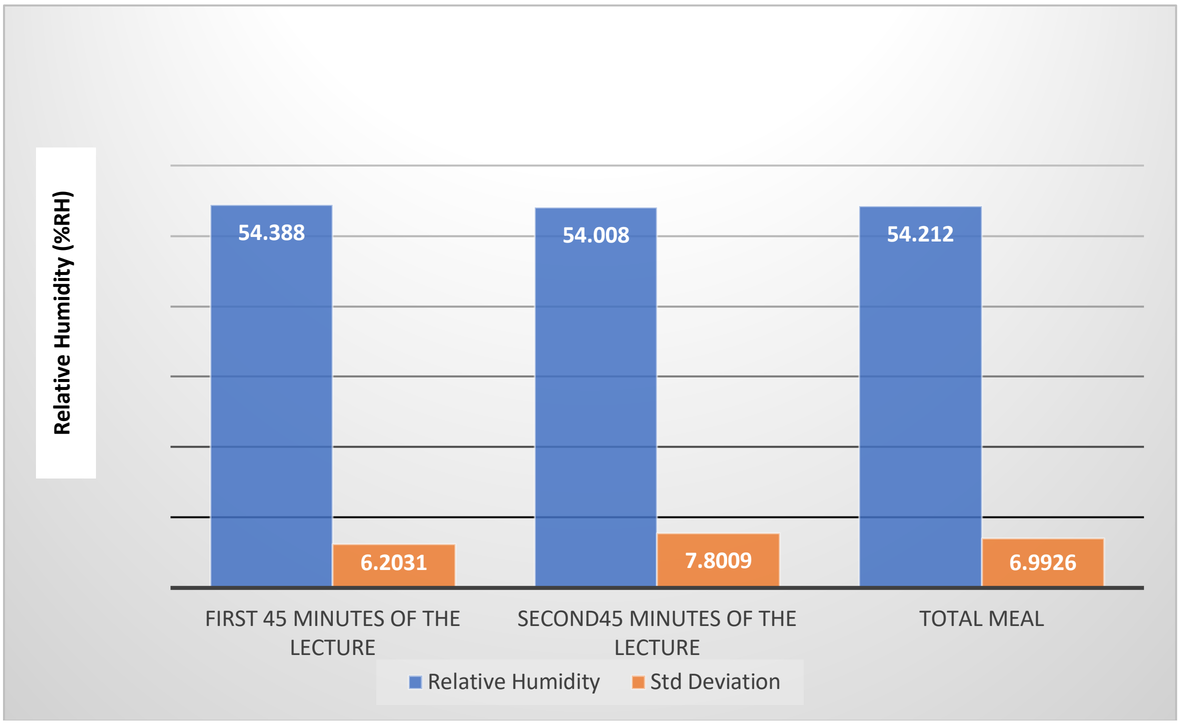
Table 7: The mean values of temperature, relative humidity, air velocity and carbon dioxide levels in the 21 classrooms measured during the study period

Number of the classroom		Temperature (degree Celsius)	Relative Humidity (%)	Carbondioxide (ppm)	Air Velocity (m/s)
Classroom 1	Mean	21.037	36.097	1026.75	0.0711
	Std. Deviation	1.2090	0.4280	254.862	0.04441
Classroom 2	Mean	25.051	30.939	1236.98	0.0728
	Std. Deviation	1.0931	1.1013	176.558	0.02877
Classroom 3	Mean	22.227	51.574	923.88	0.0956
	Std. Deviation	0.3250	3.3768	61.632	0.03087
Classroom 4	Mean	25.578	40.870	962.35	0.0868
	Std. Deviation	0.0983	0.6037	59.921	0.01629
Classroom 5	Mean	25.320	40.018	768.80	0.1177
	Std. Deviation	0.2725	0.6306	55.654	0.05842
Classroom 6	Mean	20.890	49.218	1198.18	0.0600
	Std. Deviation	0.4478	0.4248	50.899	0.02090
Classroom 7	Mean	24.304	46.889	1337.07	0.0606
	Std. Deviation	1.0213	0.6862	241.371	0.02326
Classroom 8	Mean	23.313	57.655	864.16	0.0860
	Std. Deviation	1.0806	3.3998	169.491	0.00820
Classroom 9	Mean	25.848	56.227	1903.44	0.0946
	Std. Deviation	0.4408	2.4501	451.045	0.03293
Classroom 10	Mean	25.876	55.250	649.30	0.0903
	Std. Deviation	0.6105	3.3975	25.911	0.02484
Classroom 11	Mean	26.558	50.302	611.62	0.1038
	Std. Deviation	0.1066	0.7374	33.649	0.04593
Classroom 12	Mean	21.706	45.448	609.21	0.1041
	Std. Deviation	0.5367	0.6377	52.055	0.04058

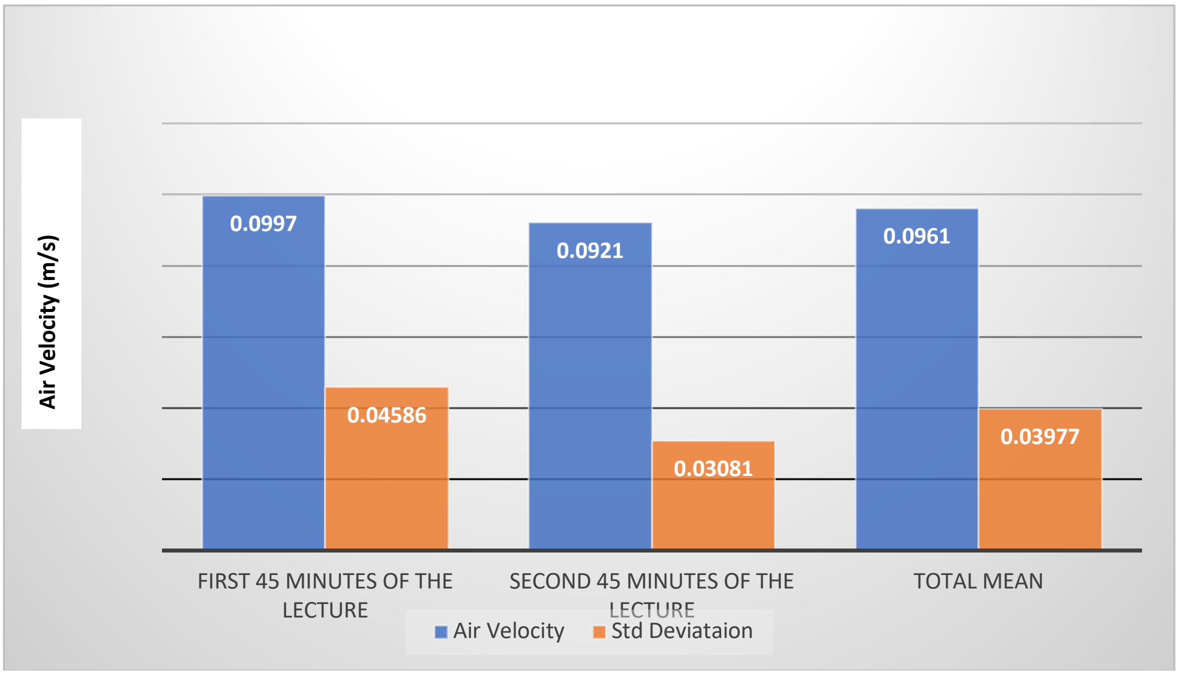
Classroom 13	Mean	25.661	44.420	1129.01	0.0904
	Std. Deviation	0.7997	1.7848	119.124	0.02035
Classroom 14	Mean	22.303	58.179	880.34	0.0995
	Std. Deviation	0.6035	1.2535	53.896	0.05451
Classroom 15	Mean	24.110	52.380	1043.97	0.0871
	Std. Deviation	0.3026	1.1745	24.454	0.02373
Classroom 16	Mean	23.426	57.743	874.10	0.0870
	Std. Deviation	0.1686	0.5077	66.049	0.01146
Classroom 17	Mean	24.908	59.505	2098.97	0.0848
	Std. Deviation	0.1828	0.2640	198.363	0.00958
Classroom 18	Mean	25.516	58.111	907.72	0.1030
	Std. Deviation	0.6496	0.1633	199.499	0.03085
Classroom 19	Mean	25.931	61.184	921.29	0.0966
	Std. Deviation	0.0731	0.2367	84.822	0.03390
Classroom 20	Mean	26.369	59.477	784.89	0.1069
	Std. Deviation	0.1730	0.4574	17.861	0.03213
Classroom 21	Mean	26.994	57.699	593.05	0.1308
	Std. Deviation	0.2857	0.6155	54.922	0.06584
Total	Mean	**24.761**	**54.212**	**995.12**	**0.0961**
	Std. Deviation	1.8410	6.9926	432.266	0.03977



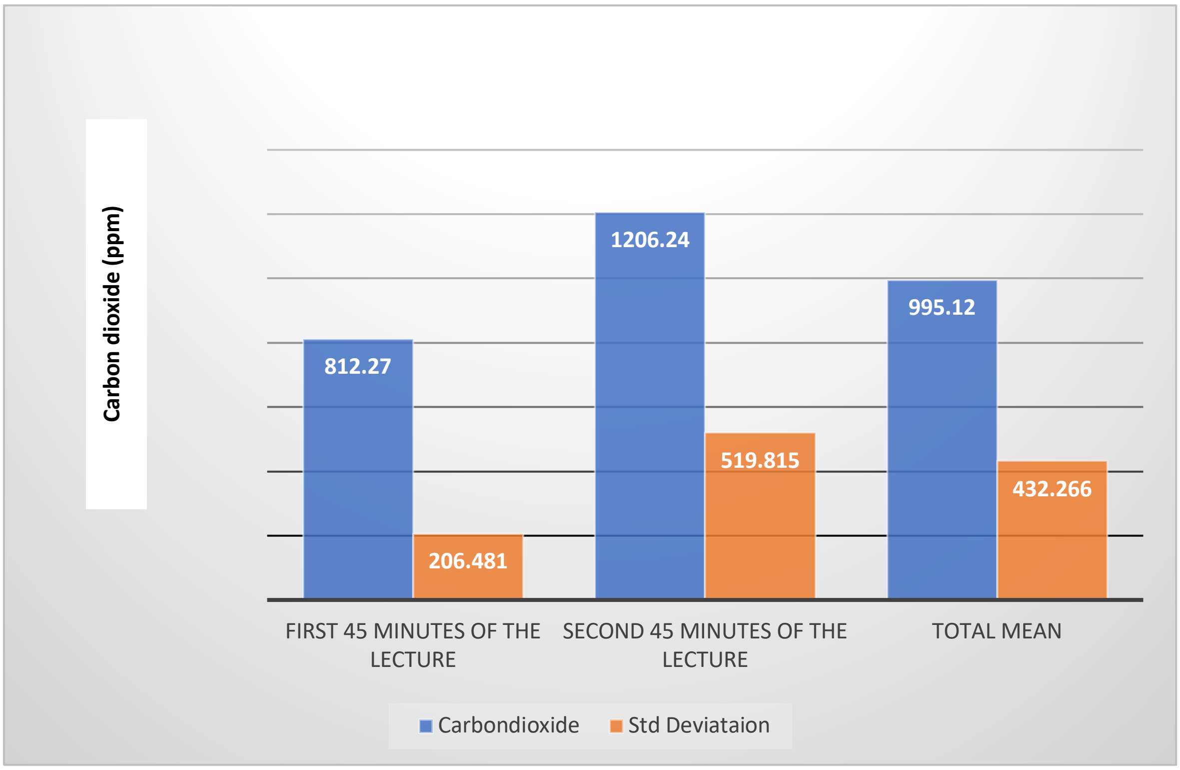
Graph 1: Mean temperature during the two halves of the lecture



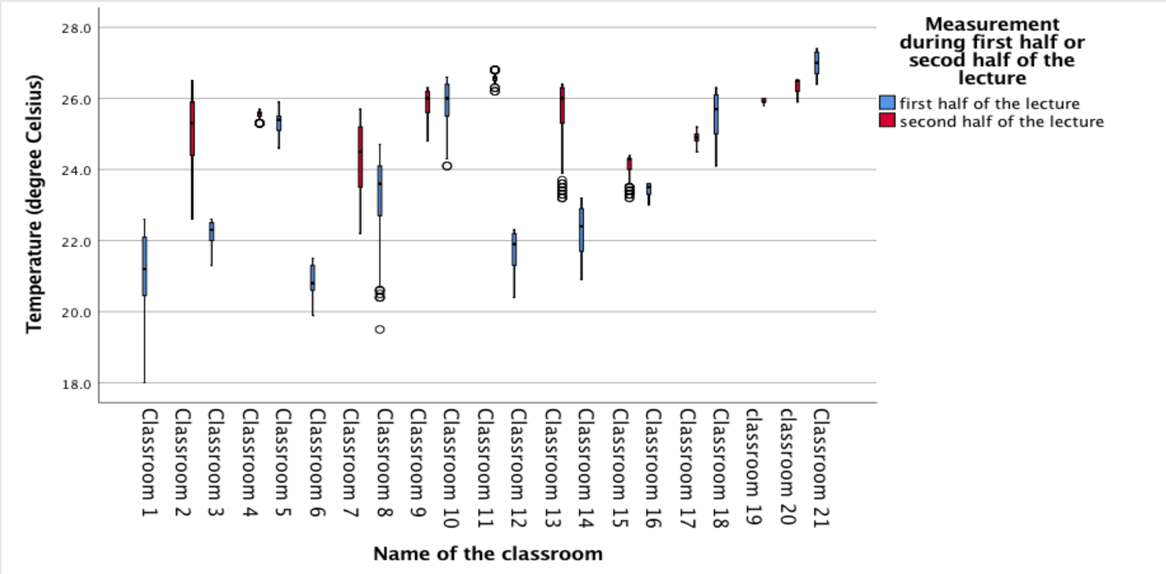
Graph 2: Mean Relative Humidity during the two halves of the lecture



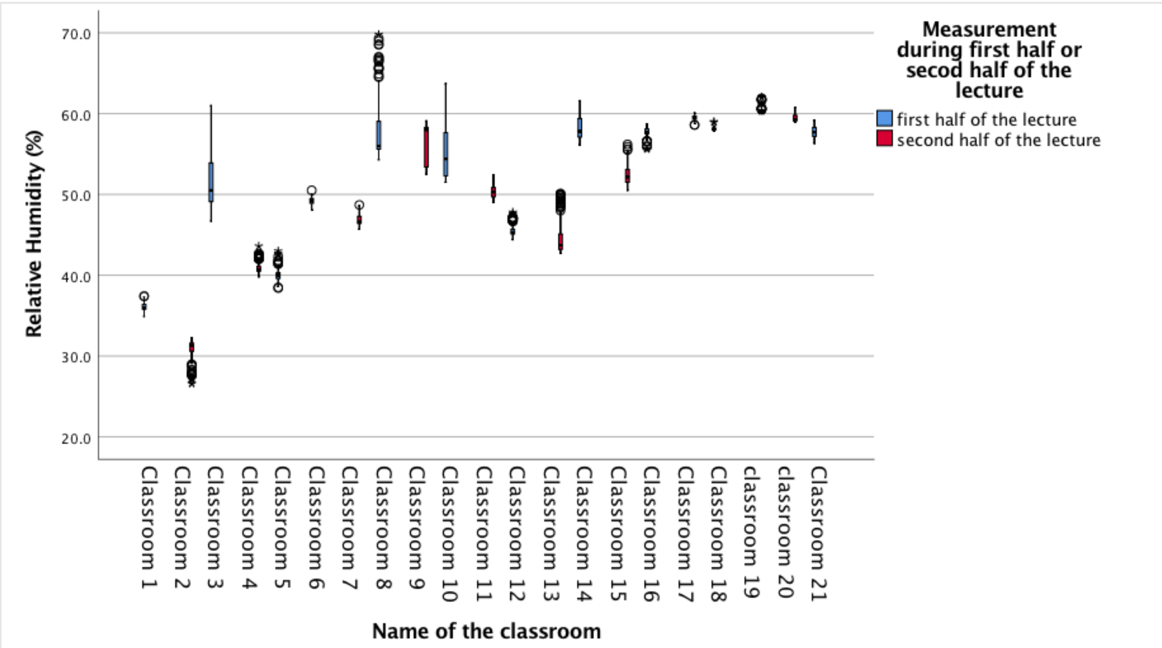
Graph 3: Indoor air velocity during the two halves of the lecture



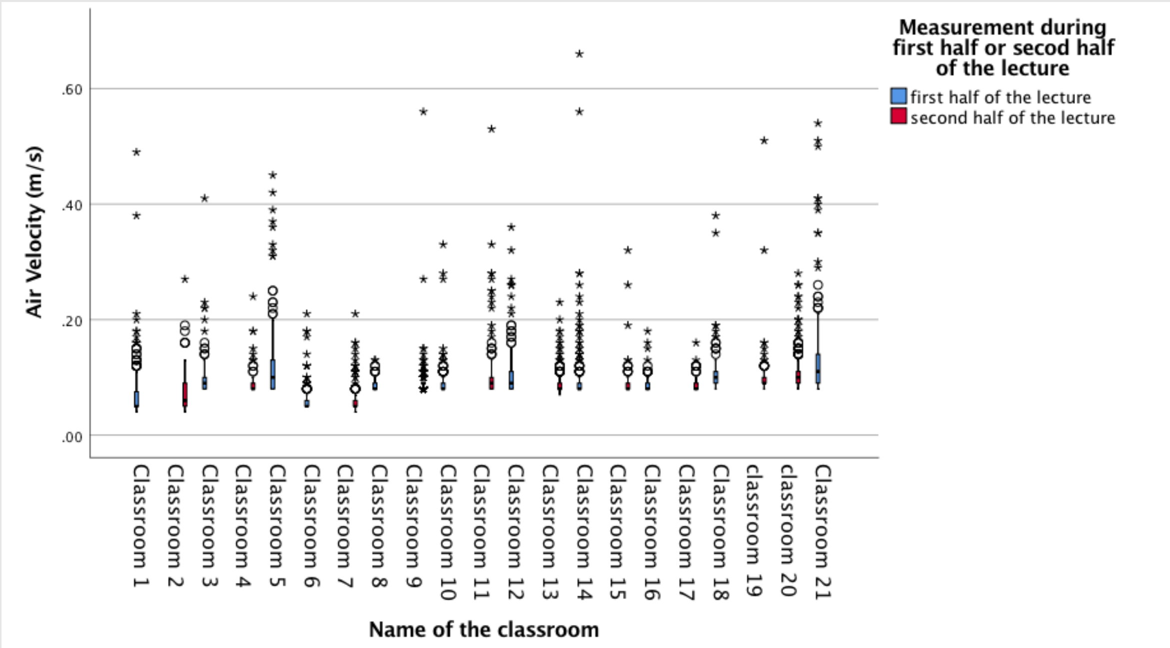
Graph 4: Mean CO_2 during the two halves of the lecture



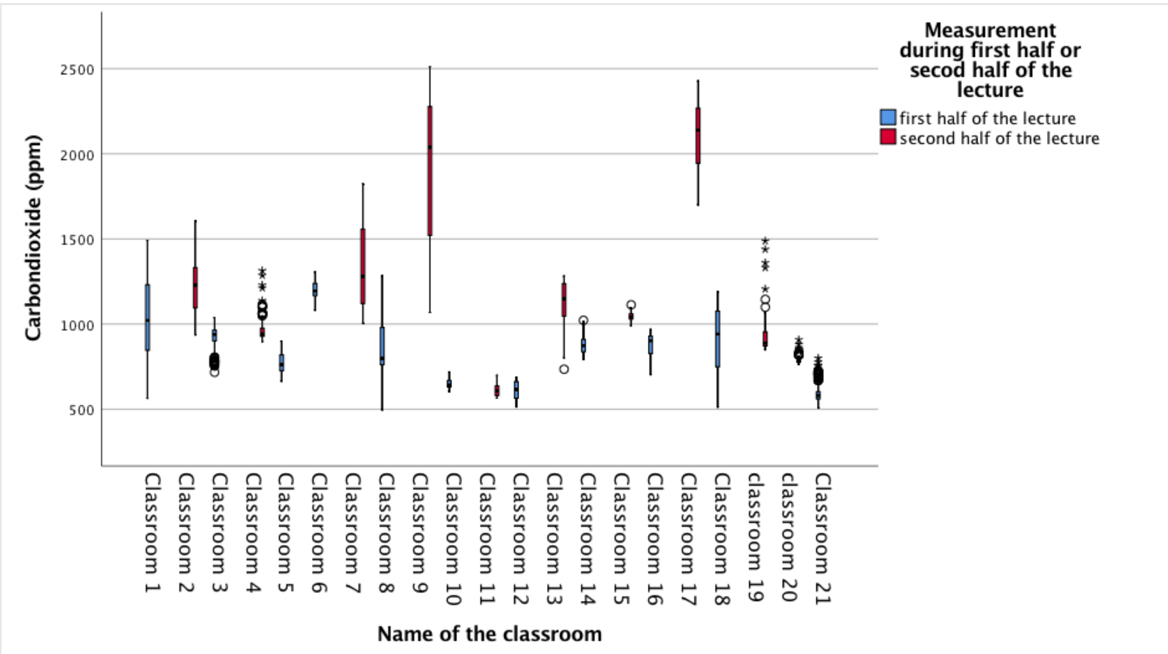
Graph 5: Clustered boxplot showing the temperature in different classrooms



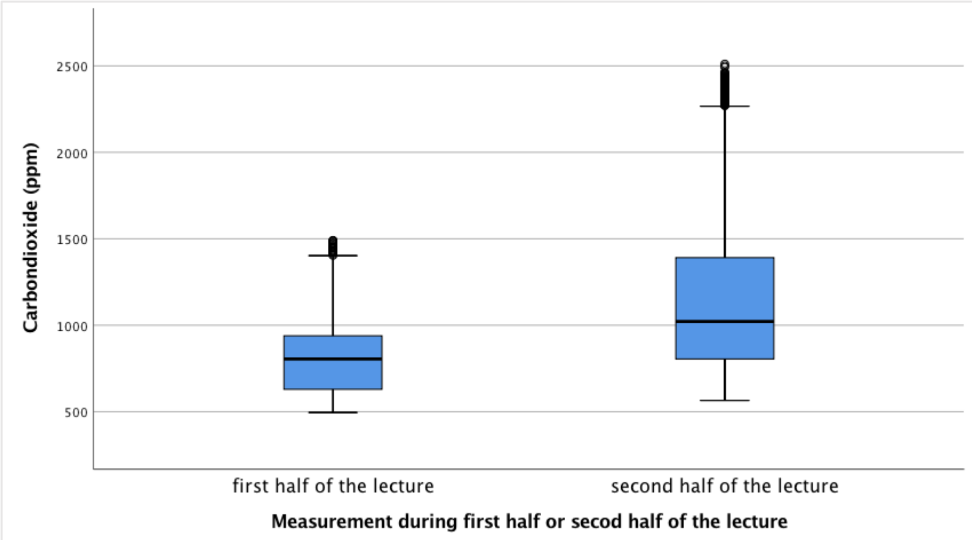
Graph 6: Clustered boxplot showing the relative humidity in different classrooms



Graph 7: Clustered boxplot showing the air velocity in different classrooms



Graph 8: Clustered boxplot showing the carbon dioxide in different classrooms



Graph 9: Simple boxplot showing the differences in mean CO2 levels measured during first half or second half of the lecture

The descriptive statistics and ANOVA along with Post hoc Tukey HSD test was run to assess the differences in the measured variables, i.e. air velocity (Table 8 and 9), carbon dioxide (Table 10 and 11), relative humidity (Table 12 and 13) and temperature (Table 14 and 15). It was observed that significant differences do exist in between the 5 schools. Each school was compared with the others using Post hoc test and it shows that the differences are significant.

Another physical environment variable measured in the study was noise in the classroom. Table 16 shows the mean, minimum and maximum values of noise in the 5 schools that participated in the study.

Table 8: Descriptive statistics and ANOVA test for Air Velocity (m/s) in different school

School	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
A	0.089	0.04263	0.0012	0.0866	0.0913	0.04	0.49
B	0.082	0.03226	0.00058	0.0817	0.084	0.04	0.56
C	0.095	0.03884	0.00072	0.0943	0.0971	0.07	0.66
D	0.085	0.01064	0.00023	0.0855	0.0864	0.08	0.18
E	0.110	0.04635	0.00065	0.1092	0.1117	0.08	0.54
Total	0.096	0.03977	0.00033	0.0955	0.0968	0.04	0.66

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	1.886	4	0.471	324.477	0.000
Within Groups	21.159	14564	0.001		
Total	23.045	14568			

Table 9: Post Hoc Tukey's HSD test for multiple comparisons of differences in mean air velocity (m/s) between the schools

School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	0.00607*	0.00128	0.000	0.0026	0.0096
	C	-0.00676*	0.00129	0.000	-0.0103	-0.0032
	D	0.00303	0.00135	0.164	-0.0007	0.0067
	E	-0.02150*	0.00120	0.000	-0.0248	-0.0182
B	A	-0.00607*	0.00128	0.000	-0.0096	-0.0026
	C	-0.01283*	0.00098	0.000	-0.0155	-0.0102
	D	-0.00304*	0.00107	0.036	-0.0060	-0.0001
	E	-0.02758*	0.00087	0.000	-0.0299	-0.0252
C	A	0.00676*	0.00129	0.000	0.0032	0.0103
	B	0.01283*	0.00098	0.000	0.0102	0.0155
	D	0.00979*	0.00108	0.000	0.0068	0.0127
	E	-0.01475*	0.00088	0.000	-0.0172	-0.0123
D	A	-0.00303	0.00135	0.164	-0.0067	0.0007
	B	0.00304*	0.00107	0.036	0.0001	0.0060
	C	-0.00979*	0.00108	0.000	-0.0127	-0.0068
	E	-0.02454*	0.00098	0.000	-0.0272	-0.0219
E	A	0.02150*	0.00120	0.000	0.0182	0.0248
	B	0.02758*	0.00087	0.000	0.0252	0.0299
	C	0.01475*	0.00088	0.000	0.0123	0.0172
	D	0.02454*	0.00098	0.000	0.0219	0.0272

Table 10: Descriptive statistics and ANOVA test for Carbon dioxide (ppm) in different school

School	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
				Lower Bound	Upper Bound		
A	981.24	211.974	5.986	969.5	992.99	564	1607
B	1085.54	498.346	8.956	1067.98	1103.11	495	2511
C	911.21	211.87	3.913	903.54	918.88	513	1282
D	1470.71	629.595	13.522	1444.2	1497.23	702	2429
E	790.51	174.413	2.437	785.73	795.28	507	1488
Total	995.12	432.266	3.581	988.11	1002.14	495	2511

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	750931651.994	4	187732912.99	1387.07	0.00
Within Groups	1971159923.397	14564	135344.68		
Total	2722091575.391	14568			

Table 11: Post Hoc Tukey's HSD test for multiple comparisons of differences in mean carbon dioxide levels (ppm) between the schools

School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-104.301*	12.314	0.000	-137.90	-70.71
	C	70.034*	12.414	0.000	36.17	103.90
	D	-489.471*	13.052	0.000	-525.08	-453.86
	E	190.737*	11.592	0.000	159.11	222.36
B	A	104.301*	12.314	0.000	70.71	137.90
	C	174.336*	9.481	0.000	148.47	200.20
	D	-385.169*	10.303	0.000	-413.28	-357.06
	E	295.039*	8.376	0.000	272.19	317.89
C	A	-70.034*	12.414	0.000	-103.90	-36.17
	B	-174.336*	9.481	0.000	-200.20	-148.47
	D	-559.505*	10.421	0.000	-587.94	-531.07
	E	120.703*	8.521	0.000	97.46	143.95
D	A	489.471*	13.052	0.000	453.86	525.08
	B	385.169*	10.303	0.000	357.06	413.28
	C	559.505*	10.421	0.000	531.07	587.94
	E	680.208*	9.427	0.000	654.49	705.93
E	A	-190.737*	11.592	0.000	-222.36	-159.11
	B	-295.039*	8.376	0.000	-317.89	-272.19
	C	-120.703*	8.521	0.000	-143.95	-97.46
	D	-680.208*	9.427	0.000	-705.93	-654.49

Table 12: Descriptive statistics and ANOVA test for Relative Humidity (%) in different school

School	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
				Lower Bound	Upper Bound		
A	39.824	6.9002	0.1949	39.441	40.206	26.6	61
B	52.894	4.5756	0.0822	52.733	53.056	45.7	69.8
C	50.126	5.9048	0.1091	49.912	50.34	42.7	61.6
D	58.601	0.9705	0.0208	58.56	58.642	55.6	60.1
E	59.012	1.3977	0.0195	58.974	59.051	56.3	62
Total	54.212	6.9926	0.0579	54.098	54.325	26.6	69.8

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	473660.226	4	118415.057	7226.211	0.000
Within Groups	238658.524	14564	16.387		
Total	712318.751	14568			

Table 13: Post Hoc Tukey's HSD test for multiple comparisons of differences in mean relative humidity (%) between the schools

School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-13.0708*	0.1355	0.000	-13.441	-12.701
	C	-10.3025*	0.1366	0.000	-10.675	-9.930
	D	-18.7777*	0.1436	0.000	-19.169	-18.386
	E	-19.1886*	0.1275	0.000	-19.537	-18.841
B	A	13.0708*	0.1355	0.000	12.701	13.441
	C	2.7683*	0.1043	0.000	2.484	3.053
	D	-5.7068*	0.1134	0.000	-6.016	-5.398
	E	-6.1178*	0.0922	0.000	-6.369	-5.866
C	A	10.3025*	0.1366	0.000	9.930	10.675
	B	-2.7683*	0.1043	0.000	-3.053	-2.484
	D	-8.4752*	0.1147	0.000	-8.788	-8.162
	E	-8.8861*	0.0938	0.000	-9.142	-8.630
D	A	18.7777*	0.1436	0.000	18.386	19.169
	B	5.7068*	0.1134	0.000	5.398	6.016
	C	8.4752*	0.1147	0.000	8.162	8.788
	E	-0.4109*	0.1037	0.001	-0.694	-0.128
E	A	19.1886*	0.1275	0.000	18.841	19.537
	B	6.1178*	0.0922	0.000	5.866	6.369
	C	8.8861*	0.0938	0.000	8.630	9.142
	D	0.4109*	0.1037	0.001	0.128	0.694

Table 14: Descriptive statistics and ANOVA test for temperature (°C) in different schools

School	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
				Lower Bound	Upper Bound		
A	23.826	2.0144	0.0569	23.714	23.937	18.0	26.5
B	24.397	2.0823	0.0374	24.324	24.470	19.5	26.8
C	23.412	1.6972	0.0313	23.351	23.474	20.4	26.4
D	24.148	0.7613	0.0164	24.116	24.180	23.0	25.2
E	26.241	0.6708	0.0094	26.223	26.260	24.1	27.4
Total	24.761	1.8410	0.0153	24.731	24.791	18.0	27.4

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18872.089	4	4718.022	2252.58	0.000
Within Groups	30504.188	14564	2.094		
Total	49376.277	14568			

Table 15: Post Hoc Tukey's HSD test for multiple comparisons of differences in mean temperature (°C) between the schools

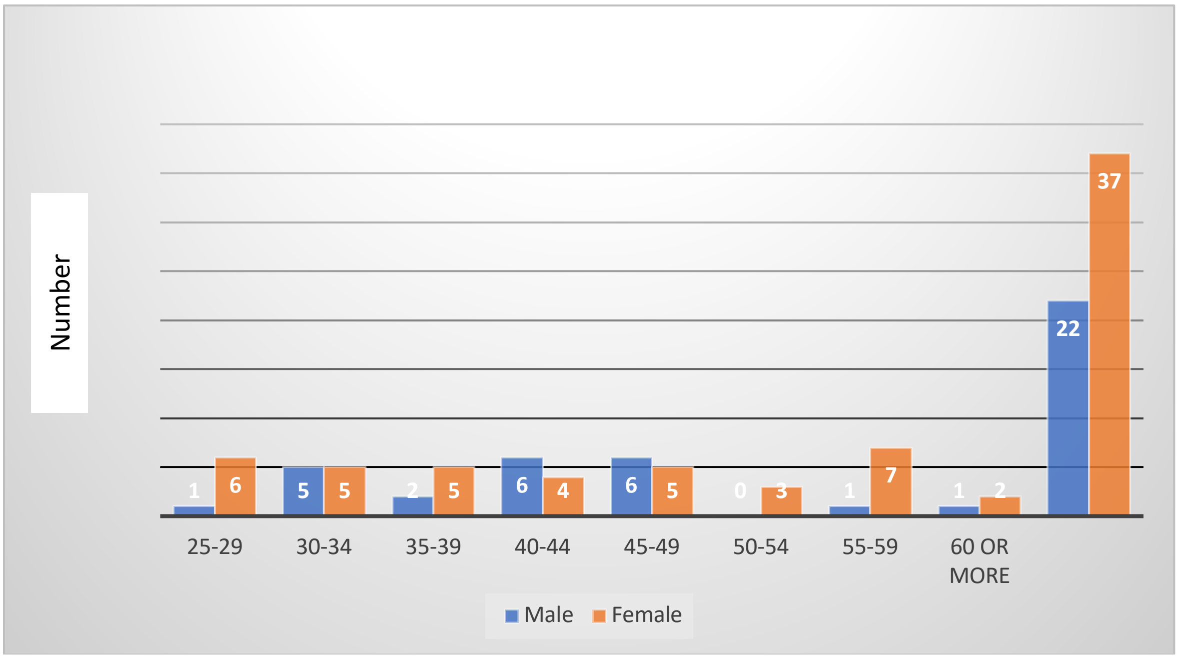
School	School	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-0.5714*	0.0484	0.000	-0.704	-0.439
	C	0.4132*	0.0488	0.000	0.280	0.546
	D	-0.3225*	0.0513	0.000	-0.463	-0.182
	E	-2.4157*	0.0456	0.000	-2.540	-2.291
B	A	0.5714*	0.0484	0.000	0.439	0.704
	C	0.9847*	0.0373	0.000	0.883	1.086
	D	0.2490*	0.0405	0.000	0.138	0.360
	E	-1.8442*	0.0329	0.000	-1.934	-1.754
C	A	-0.4132*	0.0488	0.000	-0.546	-0.280
	B	-0.9847*	0.0373	0.000	-1.086	-0.883
	D	-0.7357*	0.0410	0.000	-0.848	-0.624
	E	-2.8289*	0.0335	0.000	-2.920	-2.737
D	A	0.3225*	0.0513	0.000	0.182	0.463
	B	-0.2490*	0.0405	0.000	-0.360	-0.138
	C	0.7357*	0.0410	0.000	0.624	0.848
	E	-2.0932*	0.0371	0.000	-2.194	-1.992
E	A	2.4157*	0.0456	0.000	2.291	2.540
	B	1.8442*	0.0329	0.000	1.754	1.934
	C	2.8289*	0.0335	0.000	2.737	2.920
	D	2.0932*	0.0371	0.000	1.992	2.194

Table 16: Mean, Minimum and Maximum levels of noise (dB) in classrooms measured during the study period

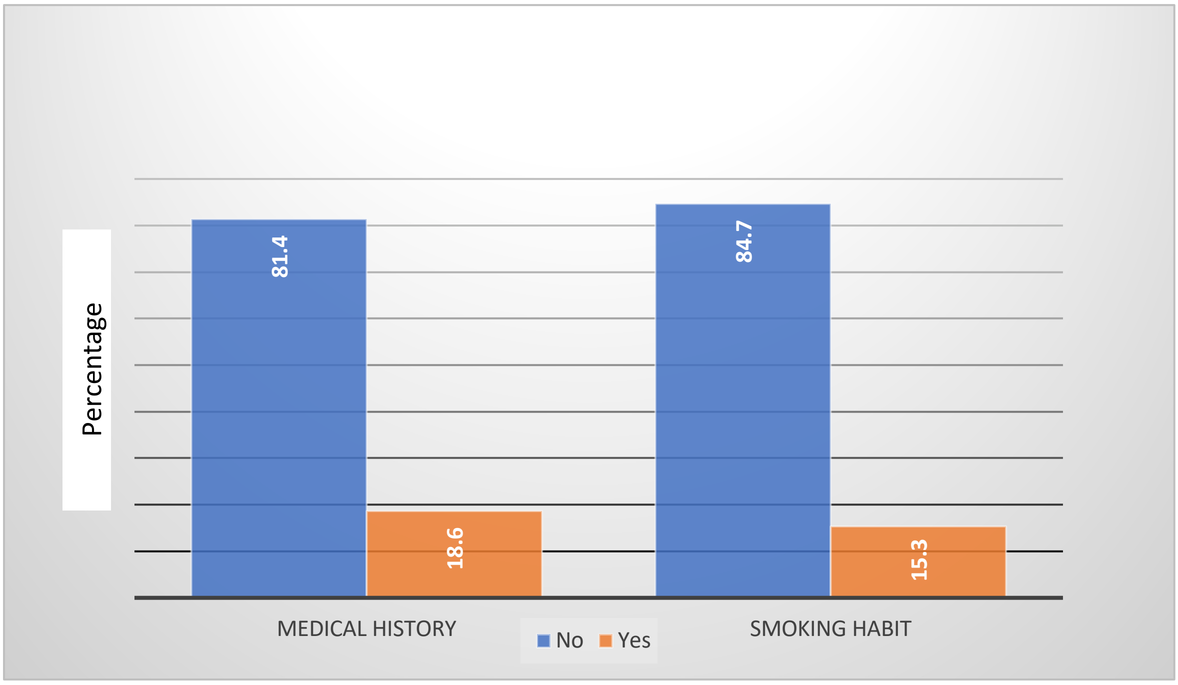
School	Classroom	Mean	Minimum	Maximum
School A	Classroom 1	67.5	52.6	84.3
	Classroom 2	61.9	43.5	91.1
	Classroom 3	67.9	35.4	108.9
	Classroom 4	51.2	36.2	78
	Classroom 5	56.2	35.6	87.6
School B	Classroom 6	52.5	36.4	77.5
	Classroom 7	55.9	37	93.2
	Classroom 8	55.6	37.1	84.5
	Classroom 9	57.1	40.9	90.6
	Classroom 10	69.5	52.3	102.2
	Classroom 11	70.1	50.1	94.5
School C	Classroom 12	54.5	36.9	80
	Classroom 13	52.7	33.6	79.5
	Classroom 14	56	35.7	88.1
	Classroom 15	65.3	44.6	100.9
School D	Classroom 16	59	38.5	87.2
	Classroom 17	56.3	33.8	87.8
School E	Classroom 18	54.5	76.1	41.2
	Classroom 19	56	40.5	82.3
	Classroom 20	57.7	41.4	81.4
	Classroom 21	35.5	56.8	91.5

5.2 Part II: The Questionnaire assessing the perception of indoor air quality and work climate and the wellbeing of the school teachers

The second part of the study consisted of a self-administered questionnaire distributed among the school teachers of the 5 participatory schools. A total of 206 printed questionnaires were distributed in the schools and a total of 75 filled questionnaires were collected back. School A, B, C, D and E returned 10 out of 40, 16 out of 50, 17 out of 28, 8 out of 44, 24 out of 54. But only 59 questionnaires could be used for statistical analysis of data as the remaining 16 were incompletely filled. The age and gender distribution of the respondents can be seen in Graph 10. More than one third of the participants had no medical history or smoking habit (Graph 11).



Graph 10: Age and gender distribution of the total study respondents



Graph 11: Medical history and smoking habit of the respondents

As reported by the study participants, the average total working hours for them per week were 40.419 hours (Table 17). The maximum total working hours per week was found to be 70 hours. The mean teaching hours per week was reported as 19.7 hours (Table 17).

Table 17: Working hours per week and years of working as reported by teachers

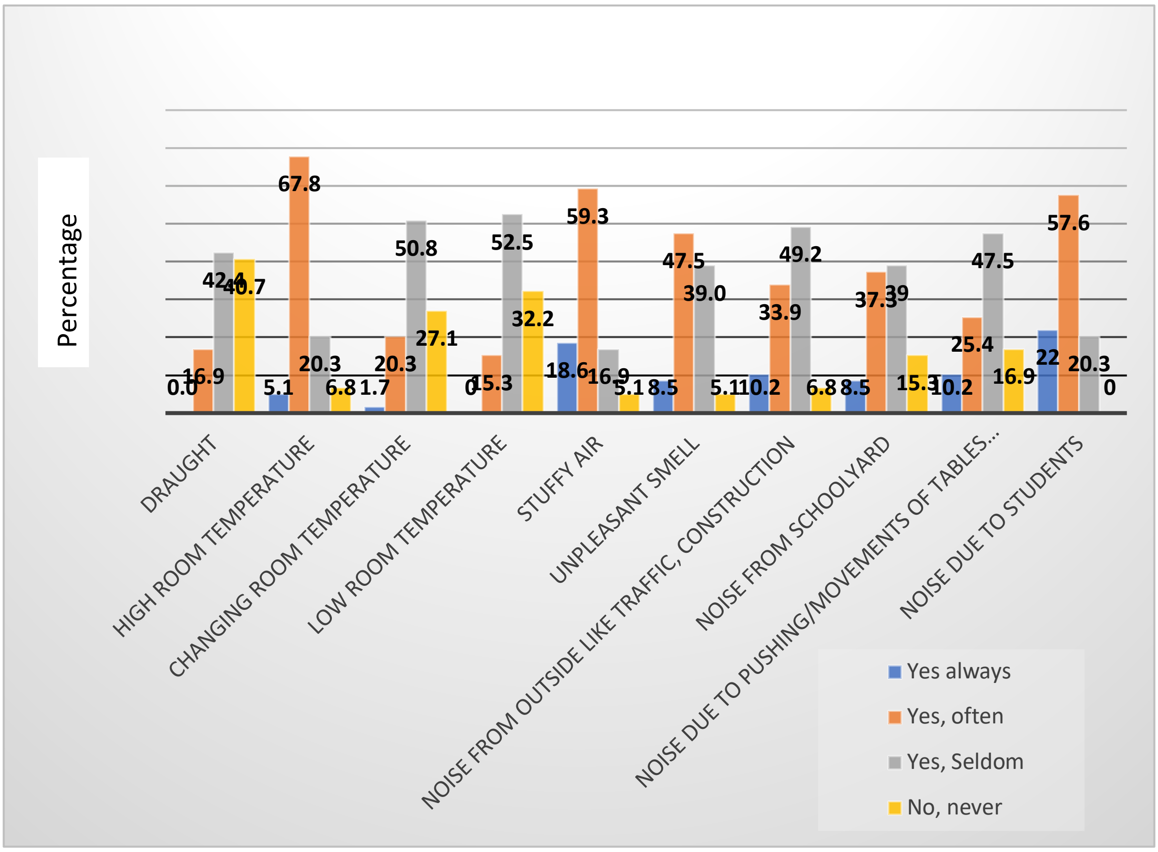
	N	Min	Max	Mean	Std. Error
Total working hours per week	59	10	70	40.419	1.6008
Teaching hours per week	59	6	29	19.798	0.7003
Years working as a teacher	59	0.5	34	13.458	1.1769

In the section about the room climate in the questionnaire, more than 50% of the respondents often experience high room temperature (67.8%), stuffy air (59.3%) and noise due to students (57.6%). About half of the study sample (47.5%) often experience unpleasant smell (Graph 12).

More than half of the study respondents had health complaints such as hoarseness/cough, headache, fatigue and difficulty in concentration. However, the belief of these respondents that the health problems were due to indoor room climate was varying (Table 18).

The mean WHO-5 Wellbeing Index score was found to be 54.19 ± 17.64 in the study sample (Table 19). The WHO-5 Wellbeing Index score was found to be normal among 61% of the school teachers, who participated in the study. Nevertheless, the remaining 27% and 12% had low mood and likely depression, respectively, according to the index (Graph 13). The odds for having WHO-5 Wellbeing Index Score 50 or less is 1.37 times for those who work for more than 40 hours per week than those who work for 40 hours or less. However, seeing the confidence intervals, the difference is not statistically significant (Table 20). Additionally, no statistically significant differences could be seen in the WHO-5 wellbeing index scores among male and female study respondents (p- 0.815) and in between different age groups (p- 0.731) (Table 21 and 22).

The perceived work climate and how intensely various factors affect the daily work routine of the respondents are described in Table 23 and 24, respectively.



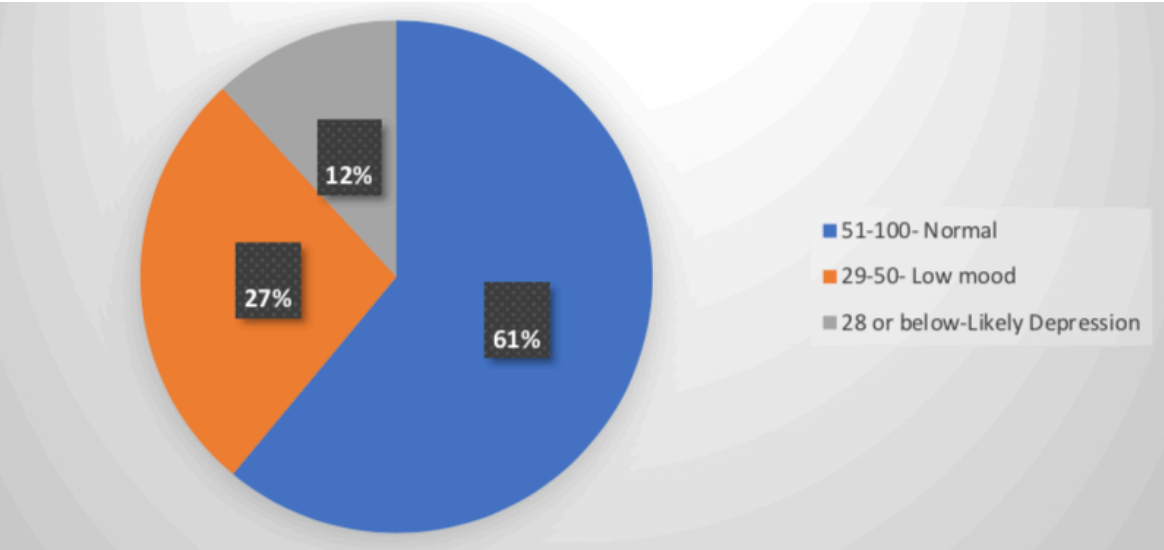
Graph 12: Graph showing the frequency of the room climate complaints among the respondents

Table 18: Frequency of health complaints by the respondents and beliefs if the symptoms are affected by indoor air quality

Frequency of health complaints amongst the respondents						**Belief of 'Yes' respondents that indoor air quality affects the respective symptom.**			
	Yes, often (every week)	**Yes, some-times**	**Yes, seldom**	**Never**	**Total Respon-dents (N)**	**Yes**	**No**	**Don't know**	**Total Yes (N)**
Itching, Burning or Irritation in Eyes	6	13	14	26	59	11	9	13	33
Hoarseness/ Cough	8	21	16	14	59	19	13	13	45
Fatigue	16	28	9	6	59	30	12	11	53
Headache	4	19	19	17	59	21	9	13	43
Difficulty in concentration	5	12	23	19	59	15	5	20	40

Table 19: The mean score of WHO-5 Wellbeing Index Scores among the study participants

	N	Mean	Std. Deviation	Std. Error	95% CI	
					Lower	Upper
WHO 5 Wellbeing Index Score	59	54.19	17.643	2.297	49.59	58.78



Graph 13: Distribution of the respondents according to WHO-5 Wellbeing Index Score

*Table 20: WHO-5 Wellbeing Score * Total Working hours per week Crosstabulation and odds ratio for WHO-5 Wellbeing Score*

		Total Working hours per week		Total
		< 40 hours	**>40 hours**	Count (%)
WHO-5 Wellbeing Score	**Score- 51 to 100** Count (%)	9 (39.1%)	14 (60.9%)	23 (100%)
	Score- 50 or less Count (%)	20 (55.6%)	16 (44.4%)	36 (100%)
Total Count (%)		29 (49.2%)	30 (50.8%)	59 (100%)

Risk Estimate- Odds Ratio for WHO-5 Wellbeing Score			
	Value	**95% CI**	
		Lower	Upper
For cohort Total Working hours per week = Less than 40 hours	0.704	0.391	1.267
For cohort Total Working hours per week = More than 40 hours	1.370	0.838	2.237
N of Valid Cases	59		

*Table 21: Gender * WHO-5 Wellbeing Score Crosstabulation and Chi-Squire Test*

			WHO-5 Wellbeing Score		Total
			Score- 51 to 100	**Score- 50 or less**	
Gender	**Male**	Count	9	13	22
		% within Gender	40.9%	59.1%	100.0%
	Female	Count	14	23	37
		% within Gender	37.8%	62.2%	100.0%
Total		Count	23	36	59
		% within Gender	39.0%	61.0%	100.0%

Chi-Square Test

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	0.055[a]	1	0.815

Table 22: Descriptive statistics for WHO-5 wellbeing scores according to the age group and ANOVA test to assess the differences in WHO-5 wellbeing scores among different age groups

Age Group	N	Mean WHO-5 wellbeing score	Std. Dev.	Std. Error	95% CI		Min	Max
					Lower Bound	Upper Bound		
25-29	7	58.86	14.36	5.43	45.57	72.15	40	76
30-34	10	55.70	20.76	6.56	40.85	70.55	21	80
35-39	7	48.00	23.43	8.85	26.32	69.68	16	76
40-44	10	60.00	20.48	6.47	45.35	74.65	24	88
45-49	11	55.27	9.435	2.84	48.93	61.61	40	68
50-54	3	53.33	2.309	1.33	47.60	59.07	52	56
55-59	8	50.00	20.28	7.17	33.04	66.96	20	72
>60	3	41.33	18.03	10.4	-3.47	86.14	24	60
Total	59	54.19	17.64	2.29	49.59	58.78	16	88

ANOVA – WHO-5 Wellbeing Index Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1432.477	7	204.640	0.628	0.731
Within Groups	16622.472	51	325.931		
Total	18054.949	58			

Table 23: Work climate at school perceived by the respondents

Work Climate	Yes, always		Yes, mostly		Yes, seldom		No, never		Total	
	N	%	N	%	N	%	N	%	N	%
I find my work interesting and motivating	8	13.6	48	81.4	3	5.1	0	0	59	100
I feel well with my colleagues	30	50.8	29	49.2	0	0	0	0	59	100
My work environment makes me feel some	13	22	36	61	8	13.6	2	3.4	59	100
There is respect, tolerance and mutual support among the colleagues	19	32.2	36	61	3	5.1	1	1.7	59	100
There is a climate of trust amongst the colleagues. Teachers can also express their opinions openly on sensitive topics.	10	16.9	36	61	12	20.3	1	1.7	59	100
Tensions and conflicts in the quorum are taken seriously and constructively.	7	11.9	32	54.2	15	25.4	5	8.5	59	100
I feel time pressure with respect to my work.	16	27.1	28	47.5	14	23.7	1	1.7	59	100
Working conditions promote collegial cooperation.	7	11.9	21	35.6	24	40.7	7	11.9	59	100
I can influence my working conditions, e.g., through flexible working hours and task allocation.	3	5.1	14	23.7	32	54.2	10	16.9	59	100

Table 24: Intensity of factors affecting the daily work routine of the respondents

Factor	**Very strongly**		**Strongly**		**Seldom**		**Not at all**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Light, space and room conditions in the teachers' room	10	16.9	23	39	21	25.6	5	8.5	59	100
Climatic conditions in the teachers' room	1	1.7	19	32.2	30	50.8	9	15.3	59	100
Dealing with integration and inclusion	8	13.6	20	33.9	18	30.5	13	22	59	100
Shortage of classrooms	10	16.9	18	30.5	20	33.9	11	18.6	59	100
Short-note change of curricula	6	10.2	11	18.6	27	45.8	15	25.4	59	100
Sick leaves of the colleagues	4	6.8	24	40.7	22	37.3	9	15.3	59	100

6. Discussion

6.1 Summary of Results

A cross-sectional study was done in 5 schools in Hamburg, Germany and the target population was school teachers, with an objective to assess the indoor air quality in classrooms and its subjective perception by the school teachers and their wellbeing.

Indoor air quality factors such as carbon dioxide, air temperature, air velocity and relative humidity along with another environmental factor viz, noise were measured in 21 classrooms of 5 different schools of Hamburg, Germany. A total of 75 filled questions were collected back from these schools. Out of 75, 59 were complete and therefore 59 questionnaires were used for statistical analysis.

6.1.1 Part 1: The objective measurements of the indoor air quality and noise in the 5 schools

In this study, it was found that the mean CO_2 level in classrooms was 995.12 ppm (Std Dev. 432.26), with a minimum and maximum value of 495 ppm and 2511 ppm respectively. Multiple studies have assessed CO_2 levels in classrooms in different parts of the world. Canha et al studied 50 classrooms in 17 schools in France and reported the mean CO_2 ppm was found to be 1290 ppm with a maximum of 2220 ppm (Canha et al., 2016). Another study conducted in 2 different schools of Frankfurt for a period of 3 weeks in the month of February and March (cold season), reported the mean value of CO_2 as 1437 ppm, 1479 ppm and 1051 ppm in week 1, 2 and 3 respectively, with a maximum value of 4840 ppm (Heudorf et al., 2009). The results of another study conducted in Portugal revealed the average indoor CO_2 concentration values in 230 classrooms as 1578.16 ± 712.49 in winter and 1152.80 ± 595.41 ppm in spring/summer (Ferreira & Cardoso, 2014). It is evident that the mean CO_2 values found in these studies do not correspond to those measured in the present study. The reasons for the divergence could be the differences in duration of measurements, differences in weather at the time of measurement, different measurement tools/instruments used, variation in the number of occupants in the classrooms and the smaller number of sample classrooms in the present study. It also depends on the activity of the people, volume of the room and air exchange number (ventilation) (UBA, 2008). Furthermore, insufficient ventilation is likely to be more conspicuous during the winter season as the windows and doors remain closed often (Methods for monitoring indoor air quality in schools, 2011).

H. Fromme et al measured indoor CO_2 concentrations using testo 445 instrument in 92 and 75 classrooms in Munich during winter and summer season, respectively. It was seen that the CO_2 concentrations in the classrooms varied between 598 and 4172 ppm (median: 1608 ppm) in winter, and between 480 and 1875ppm (median: 785 ppm) in summer (Fromme et al., 2007). The CO_2 levels in classrooms during summer (480 – 1875 ppm) reported by H. Fromme et al can be considered to be in the line of agreement to those of the present study (495 -2511 ppm).

The current study finds the mean temperature of classrooms during the spring/summer season as 24.7 ± 1.84 °C. This finding is comparable to the findings of Fromme H et al , who reported the mean temperature in classrooms during summer as 25 °C (Fromme et al., 2008). However, the mean temperature in classrooms of present study lies in the recommended range of 20 - 26 °C ("School environment: Policies and current status," n.d.). Similar are the findings of another study conducted by Kalimeri et al in 2016 in 3 schools of Greece. The temperature range in the non-heating period reported by Kalimeri et al is 20 to 26 °C (Kalimeri et al., 2016). Another study conducted by Canha et al in France, in which measurements were done in 51 classrooms and reported the mean temperature in heating season and non-heating season as 22.5 ± 1.5 °C and 23.6 ± 1.3 °C, respectively.

The temperature range found in the present study conducted in the schools of Hamburg (north Germany) is 18 – 27.4 °C, which varies from the summer temperature range (21 – 29.1 °C) findings of a study conducted in Frankfurt (south Germany) (Heudorf et al., 2009). Though Heudorf et al reported the winter temperature range in classrooms as 18 – 25.1 °C. This difference could be due to the variance in the weather of southern and northern regions of Germany.

The relative humidity reported in the study by Fromme et al was found to be lower (Mean RH: 51%) (Fromme et al., 2008) than that of the present study (Mean RH: 54.2 ± 69.9%). Nonetheless, the RH levels of present study, when compared to the recommended values of RH in schools are found to be slightly higher than the upper range (30% - 50%) ("School environment: Policies and current status," 2015). In Greece, a study conducted in 3 schools in the year 2016, the average relative humidity ranged from 40.1 ± 2.1 to 52.2 ± 2.6% for the non-heating period and from 31.4 ± 6.3 to 50.7 ± 3.3% for the heating period (Kalimeri et al., 2016). The relative humidity range (26.6 – 69.8%) of the present study are not in line of agreement of the RH range for non-heating period reported by Kalimeri et al. The current study findings of temperature and relative humidity can be compared to the findings of a study conducted in Lisbon, where the temperature varied between 18.6°C and 28.2°C, and RH was in the 25.1 – 66.8% interval (Pegas et al., 2011).

The mean CO2 level in classrooms during the first and second 45 minutes of lecture was 812.27 ± 206.481 ppm and 1206.24 ± 519.815 ppm, respectively. The later exceeds the recommended level of 1000 ppm ("School environment: Policies and current status," 2015), which can be due to the increasing exhalation of CO2 by the occupants over the time in a lecture and insufficient ventilation through windows. Also, it is evident that the mean temperature of classrooms, where measurements were carried out during second 45 minutes of the lecture is slightly higher than that of the first 45 minutes of the lecture. The reason for this difference is not clear. However, no differences can be seen in the mean values of indoor relative humidity and air velocity during the first and second 45 minutes of the lecture.

In table 25, the mean CO_2 level of present study has been compared to the findings of a few other studies found in the literature.

The present study measured the noise levels in 21 classrooms of 5 schools and found that the mean noise level ranges from 35.5 to 70.1 dB (A), with minimum and maximum values as 33.6 dB (A) to 108.9 dB(A), respectively. The wide range of noise level in the classrooms could be attributed to the reason that the activities were different in each classroom during the measurements (for e.g., group work, watching video, listening to the lecture etc), and also to the fact that the number of students and grade of each classroom was different (from 5th grade to 11th grade). However, research shows that in schoolchildren and teachers are exposed to mean sound levels ranging from 65 and 87 dB (A) and peak sound levels of 100 dB (A) (Eysel-Gosepath, Daut, Pinger, Lehmacher, & Erren, 2012).

Table 25: Comparison of mean CO_2 levels of present study with other studies

Author and Year	**Place**	**Number of schools / classrooms**	**Mean CO_2 levels (ppm)**	**Measuring instrument**	**Comments in comparison with findings of present study (Mean CO_2 level- 995ppm)**
Fromme et al., 2007	Munich, Germany	92 classrooms in winter and 75 classrooms in summer	Winter: 1603 Summer- 405	Testo 445	Mean during summer season is lower
Heudorf et al., 2009	Frankfurt, Germany	4 classrooms in 2 schools	Week 1: 1437 Week 2: 1479 Week 3: 1051	QTRAK CN50274	The measurements were done over 1week period.
Pegas et al., 2015	Lisbon	14 schools	Range: 705 to 6,821	IQ-610, GrayWolfÒ monitor	The range is too wide, and the measurements were done for 8 hours occupancy periods
Yang et al., 2015	Seoul, Korea	348 rooms in 116 schools	Range: 605 to 988	Non-dispersive infrared (NDIR) method using an analyzer (Model 200E, 300E and 360E, Teledyne, United States)	Comparable to present study but the measurements in each room were done for 5 hours
Canha et al., 2017	France	50 classrooms in 17 schools	1290	Q-Trak Plus IAQ monitor 8552	Higher than the present study
Hänninen et al., 2017	Albania	36 classrooms	2700	Delta Ohm models HD21AB and HD21AB17	The mean is very high, but the measurements were done during winter season.

According to the findings of present study, the indoor air quality in the 11 classrooms where measurements were carried out during first 45 minutes of the lecture, can be classified as IDA 2 (Medium air quality; absolute indoor CO2 levels > 800 - 1000 ppm). Whereas, for the remaining 10 classrooms where measurements were run in during second 45 minutes of the lecture, the air quality can be classified as IDA 3 (Moderate air quality; absolute indoor CO2 levels > 1000 – 1400 ppm). This finding is contradictory to the findings of a study done in Poland by Mainka A & Zajusz-Zubek E, in which the air quality was classified as IDA 4 (91.0% of compulsory care/teaching time) (Mainka & Zajusz-Zubek, 2015).

6.1.2 Part 2: The Questionnaire assessing the perception of indoor air quality and work climate and the wellbeing of the school teachers

In the present the most often indoor air problems were high and low room temperature (yes, often: 67.8 % and 52.5% respectively), stuffy air (yes, often: 59.3%), noise due to students (yes, often: 57.6%), changing room temperature (yes, often: 50.8%) and unpleasant smell (yes, often: 47.5%). These findings contradict the findings of a study conducted in offices and schools in Finland by Reijula K, where it was reported that problems such as varying temperature, high and low temperature and unpleasant odors occur occasionally. However, complaints regarding stuffy air and noise were often (Reijula & Sundman-Digert, 2004).

Problems such as noise due to students, noise from schoolyard, and noise from outside like traffic, construction etc is often faced by 57.6%, 37.3% and 33.9% of the respondents respectively. Eysel- Gosepath K. conducted a study among the teachers of 5 schools in Cologne, Germany and found that 48% of these teachers considered that the noise levels in corridor are often high and 47% considered noise in classrooms as often high (Eysel-Gosepath et al., 2012).

In this study, around 80% of the respondents had no medical history or smoking habit. The most common health complaint among the current study participants was found to be fatigue (27.1%), followed by hoarseness/cough (13.5 %), itching, burning or irritation in eyes (10.1%), difficult in concentration (8.4%) and then headache (6.7%). These findings do not correspond to a study conducted in Finland, where the most common complaint was itching, burning or irritation of the eyes (17%) followed by fatigue (16%), hoarseness, dry throat (14%), headache (7%) and then difficulty in concentration (3%) (Reijula & Sundman-Digert, 2004). However, Scheuch K et al mentions that the common complaints among teachers in

Germany are exhaustion and fatigue, headaches, tension, listlessness, sleep and concentration disorders, inner restlessness, and increased irritability (Scheuch et al., 2015).

Another component of the questionnaire was the WHO-5 well-being index. The. average wellbeing score in this study was 54.19 ± 17.643. In comparison to the subjective wellbeing score of Europe (above 65) and Germany (around 70) (Parent-Thirion et al., 2017), the average score of teachers in this study is low. One explanation for this finding could be an extra workload of teachers apart from teaching such as correcting papers, preparing for lessons, supervision of students, interacting with parents etc (Bauer et al., 2007). The findings of the current study show that the average working hours per week (40.4 ± 1.6) are approximately double the average teaching hours per week (19.7 ± 0.7). Nevertheless, around 60% of the present study respondents had normal wellbeing score of more than 50.

Among the study participants, around 50% of them mostly felt time pressure with respect to their work and around similar number felt that they can seldom influence their working conditions through flexible working hours or task allocation. This can lead to stress and studies have shown that feeling stressed is associated with poorer well-being and more depressive symptoms (Kidger et al., 2016).

6.2 Limitations of the study:

1. The primary limitation of this study is the cross-sectional study design. The data collection was done at a specific point of time, and therefore no causal associations can be proved (Carlson & Morrison, 2009).
2. Due to limited sources on the part of the researcher and limited time on part of the schools, the measurements were run with the convenience of both.
3. Also, the classrooms were of different sizes/volumes, on different floors and directions and the number of occupants varied. Twice it was observed that the students moved out of the class for their allotted group work for about half of the measurement duration. So, even the number of occupants was not constant throughout that particular measurement.
4. The measurements were done on different days from the month of April to July. The weather was different on different days of measurement. A few days were sunny and warm, and the other days were cold, rainy or windy in Hamburg. Besides, measurements were carried out from early morning until late evening.
5. The frequency of opening and the number and size of the windows varied in different classrooms. This affects the ventilation rate and thus the indoor climate parameters. Under Länder building regulations, it is strictly prohibited to use windowless rooms for long periods of occupation, and therefore also as classrooms in schools (UBA, 2008). In this study, it was found that even though the classrooms had windows in one of the schools, but they were unable to open it.
6. The participation rate for objective measurements of classrooms in schools was low. Only 5 schools agreed to participate in the study. Likewise, the number of teachers from these schools who participated in the subjective part of the study was limited.
7. An additional limitation was the collection of data with an unvalidated questionnaire. The reliability of the questionnaire was not assessed either.
8. The questionnaires were handed over to one teacher in each school. So, the proper distribution of questionnaires among the study population is questionable.
9. The filled questionnaire was considered as an informed consent of the respondents.

6.3 Strengths of the study

1. Albeit the shortcomings of cross-sectional studies, these are “most appropriate for screening hypotheses because they require a relatively shorter time commitment and fewer resources to conduct" (Carlson & Morrison, 2009)
2. The study parameters were measured with the multifunctional device ‘testo 480’, which is comprised of the comfort probe, the IAQ probe, and the globe thermometer. The measurement accuracy for testo 480 probes corresponds with the recommendations from ASR A3.5 (2010).
3. The combination of objective measurements and assessment of subjective perceptions adds to the strength of the study.
4. In order to reach the study population, the 19-itemed questionnaire was developed in German language for collecting the subjective information regarding the perception of indoor climate as well as work climate and to assess the wellbeing.

6.4 Recommendations

1. Ventilation rate or indoor air quality measured in one classroom cannot may not be representative of other classrooms in the school building. Measurements will need to be conducted in several classrooms simultaneously (Methods for monitoring indoor air quality in schools, 2011).
2. It is recommended that in summer, proper ventilation should be done every 60 minutes for 3 - 10 minutes and in winter for 3 minutes (ASR A3.6, 2012). According to Schild and Willems, 4-6 minutes of ventilation is required for the complete exchange of air in winter seasons and in summer season 25-30 minutes are needed for the same (Schild K. & Willems W. M., 2011).
3. Proper ventilation (natural or ventilation or adjustment of air conditioning systems) is recommended when the relative air humidity is above 50% (DGUV, 2010).
4. The increase in air velocity through ventilation is helpful in reducing high indoor air temperatures (ASR A3.5, 2010).
5. Since most schools use natural ventilation ("School environment: Policies and current status," 2015), it is necessary to at least have the possibility of opening all windows, when required.
6. Indoor air quality infrared CO_2 monitor with possibilities of: traffic light system and buzzer; oxygen concentration; temperature; atmospheric pressure and relative humidity measurements ("CO2 Carbon Dioxide EMS Environmental Monitoring System with traffic light option, 0-3000ppm or 0-5000ppm CO2," n.d.) (UBA, 2008) should be installed in the classrooms to alert teachers to open the windows for natural ventilation in case of poor air quality, or to adjust the ventilation in Heating, Ventilating and Air Conditioning (HVAC) systems, if available (Stabile et al., 2017).
7. Considering the climate change and the need for saving energy in future, the new school buildings should be built according to passive-house standard. Heudorf U concluded that the mean CO_2 levels were lower in the passive-house school as compared to those in conventionally ventilated schools, i.e., ventilation via opening the windows (Heudorf, 2007).
8. Further research should be done to assess the levels of indoor air pollutants such as Particulate matter, Formaldehyde, NO2, Benzene, Carbon monoxide and other chemical pollutants along with the variables of the present study for more detailed and accurate analysis of the situation.

9. To gather a real picture regarding the well-being score of school teachers in Germany, further research is recommended.

7. Conclusion

The indoor air quality in the studied classrooms was found to be medium air quality accordance with DIN EN 13779: 2007-09. The mean CO2 levels in the 21classrooms of 5 schools is 995 ppm. However, the mean CO_2 levels in the classrooms measured during second 45 minutes of lecture (1206 ppm) exceed the recommended CO2 level (1000 ppm) and is higher than the mean value measurements done during the first 45 minutes of lecture (812 ppm). The mean relative humidity (54.2 ± 69.9 %) in the classrooms exceeds the recommended range of 30 – 50% in schools, whereas the mean indoor air velocity (0.09 ± 0.03 m/s) is lower than the recommended range of 0.15 – 0.30 m/s during summer. This indicates that the ventilation in the studied classrooms is not enough for the complete air exchange. Nevertheless, the mean indoor temperature (24.7 ± 1.84 C) in the classrooms was within the recommended ranges of 20 – 26 °C. Clean air being a basic requirement of life, is additionally an important determinant of healthy life and people's wellbeing. Investigating the indoor air quality in schools will help to assess the level of indoor air pollution in schools and take necessary corrective measures, if necessary.

The common indoor climate problems perceived by the teachers were high and low room temperature, stuffy air, noise due to students, changing room temperature and unpleasant smell. Moreover, the most common complaint was fatigue followed by hoarseness/cough. The mean WHO-5 wellbeing Score was 54.19 ± 17.64, yet around 39% of the study participants had below normal (0 - 50) WHO-5 wellbeing score. However, due to limited resources and the limitations in data collection, no association could be tested between the objective and subjective variables. It is recommended to conduct further research to see any association between the indoor climate and wellbeing.

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9. Annexures

Annexure I: The Questionnaire

Einfluss des Raumklimas in Schulen auf das Wohlbefinden von Lehrerinnen und Lehrern

Als Lehrkraft sind Sie in Ihrem Arbeitsalltag vielfältigen Bedingungen ausgesetzt. In der Studie „Einfluss des Raumklimas in Schulen auf das Wohlbefinden" möchten wir herausfinden, wie das kollegiale Miteinander und physische Einflussfaktoren, wie z.B. Lärm, Lufttemperatur, Luftfeuchtigkeit sich auf Ihr gesundheitliches Wohlbefinden auswirken. Deshalb bitten wir Sie an dieser Studie teilzunehmen. Bitte beantworten Sie die Fragen offen und ehrlich, nur so kann ein realistisches Bild entstehen, um Verbesserungsvorschläge erarbeiten zu können.

Das Forschungs- und Transferzentrum „Nachhaltigkeit und Klimafolgenmanagement" (FTZ-NK) der Hochschule für Angewandte Wissenschaften Hamburg nimmt den Schutz Ihrer persönlichen Daten sehr ernst. Ihre Daten werden unter Beachtung der geltenden datenschutzrechtlichen Bestimmungen vertraulich behandelt und nicht an Dritte weitergegeben. Die Umfrageergebnisse werden seitens des FTZ-NK ausschließlich in zusammengefasster Form für die Auswertung und Erarbeitung von Verbesserungsvorschlägen verwendet und lassen somit keine Rückschlüsse auf Individuen zu. Mit Ihrer Teilnahme willigen Sie in die Speicherung, Verarbeitung und Verwendung der Daten ein und helfen uns ein wichtiges Thema zu erforschen.

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Einfluss des Raumklimas in Schulen auf das Wohlbefinden von Lehrerinnen und Lehrern 1

Persönliche Angaben					
1.	Geschlecht:		☐ männlich	☐ weiblich	
2.	Welcher Altersgruppe gehören Sie an?		☐ 25-29	☐ 30-34	☐ 35-39
	☐ 40-44	☐ 45- 49	☐ 50-54	☐ 55- 59	☐ > 60
3.	Wie viele Jahre insgesamt sind Sie als Lehrer/-in tätig?				
4.	Wie lange sind Sie an Ihrer jetzigen Schule tätig?				
	☐ 0-2 Jahre	☐ 3-5 Jahre	☐ 6-10 Jahre	☐ 11-20 Jahre	☐ > 20 Jahre
5.	Wie viele Zeitstunden arbeiten Sie durchschnittlich pro Woche im Schuldienst? Bitte berechnen Sie die Zeit für Vor- und Nachbereitung sowie andere Tätigkeiten mit ein. .... Zeitstunden pro Woche Wie viele Zeitstunden davon sind reine Unterrichtsverpflichtung? .... Zeitstunden pro Woche				
6.	Sind Sie Klassenlehrer/in?	☐ Ja		☐ Nein	
7.	Welche Klassenstufen unterrichten Sie? (Mehrere Antworten möglich)				
	☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12				
8.	Welche Fächer unterrichten Sie?				
9.	Wie viele Schüler/ -innen unterrichten Sie durchschnittlich in einer Klasse?				
	☐ bis 20	☐ 21 bis 25	☐ 26 bis 30	☐ > 30	

Raumklima

10. Haben Sie sich *während der letzten 3 Monate* durch eine oder mehrere der folgenden Bedingungen im Klassenraum beeinträchtigt gefühlt?

		Ja, immer	Ja, häufiger	Nur selten	Nein, nie
a)	Zugluft	☐	☐	☐	☐
b)	Hohe Raumtemperatur	☐	☐	☐	☐
c)	Wechselnde Raumtemperatur	☐	☐	☐	☐
d)	Niedrige Raumtemperatur	☐	☐	☐	☐
e)	Schwüle/ muffige Luft	☐	☐	☐	☐
f)	Unangenehmer Geruch	☐	☐	☐	☐
g)	Lärm von außen (z.B. Verkehr, Bauarbeiten)	☐	☐	☐	☐
h)	Lärm vom Schulhof	☐	☐	☐	☐
i)	Lärm durch Verrücken von Tischen und Stühlen	☐	☐	☐	☐
j)	Lärm durch Schüler im Klassenraum	☐	☐	☐	☐
k)	Andere Gründe:				

11. Gibt es in Ihrer Schule ein technisches Lüftungssystem? ☐ Ja ☐ Nein

12. Können Sie den Klassenraum durch das Öffnen von Fenstern lüften? ☐ Ja ☐ Nein

Wenn Ja: Wie oft lüften Sie pro Unterrichtsstunde?
☐ Immer ☐ Manchmal ☐ Selten ☐ Nie

Einfluss des Raumklimas in Schulen auf das Wohlbefinden von Lehrerinnen und Lehrern 2

HAW HAMBURG

Gesundheit

13. Welche der folgenden Symptome hatten Sie während der *letzten 3 Monate*?

		Ja, oft (jede Woche)	Ja, manch-mal	Ja, selten	Nie	Wenn Ja: Glauben Sie dass das Raumklima das jeweilige Symptom beeinflusst? Ja	Nein	Weiß nicht
a)	Juckende, brennende und/ oder gereizte Augen	☐	☐	☐	☐	☐	☐	☐
b)	Heiserkeit und/ oder Husten	☐	☐	☐	☐	☐	☐	☐
c)	Müdigkeit	☐	☐	☐	☐	☐	☐	☐
d)	Kopfschmerzen	☐	☐	☐	☐	☐	☐	☐
e)	Konzentrationsstörungen	☐	☐	☐	☐	☐	☐	☐
f).	Andere Symptome..................................							

14. Haben Sie Vorerkrankungen? ☐ Nein ☐ Ja Welche ....

15. Rauchen Sie? ☐ Ja ☐ Nein ☐ Keine Angabe

16. Nehmen Sie Schlaf- oder Beruhigungsmittel?

☐ Regelmäßig ☐ Manchmal ☐ Selten ☐ Nie ☐ Keine Angabe

Wohlbefinden

17. Bitte markieren Sie bei jeder Aussage die Rubrik, die Ihrer Meinung nach am besten beschreibt, wie Sie sich *in den letzten 2 Wochen* gefühlt haben.

In den letzten 2 Wochen...	Die ganze Zeit	Meistens	Etwas mehr als die Hälfte der Zeit	Etwas weniger als die Hälfte der Zeit	Ab und zu	Zu keinem Zeitpunkt
war ich froh und guter Laune	☐	☐	☐	☐	☐	☐
habe ich mich ruhig und entspannt gefühlt	☐	☐	☐	☐	☐	☐
habe ich mich energetisch und aktiv gefühlt	☐	☐	☐	☐	☐	☐
habe ich mich beim Aufwachen frisch und ausgeruht gefühlt	☐	☐	☐	☐	☐	☐
war mein Alltag voller Dinge, die mich interessieren	☐	☐	☐	☐	☐	☐

Einfluss des Raumklimas in Schulen auf das Wohlbefinden von Lehrerinnen und Lehrern 3

HAW HAMBURG

Arbeitsbedingungen					
18.	Wie schätzen Sie die folgenden Bedingungen an Ihrer Schule ein?				
		Ja, immer	Ja, meistens	Ja, selten	Nein, nie
a)	Ich empfinde meine Arbeit als interessant und motivierend.	☐	☐	☐	☐
b)	Ich fühle mich wohl im Kollegium.	☐	☐	☐	☐
c)	Die Arbeitsbedingungen geben mir ein Gefühl der Sicherheit.	☐	☐	☐	☐
d)	Der Umgang im Kollegium ist von Respekt, Toleranz und gegenseitiger Unterstützung geprägt.	☐	☐	☐	☐
e)	Im Kollegium herrscht ein Klima des Vertrauens, d.h. auch heikle Themen können diskutiert werden.	☐	☐	☐	☐
f)	Spannungen und Konflikte im Kollegium werden ernst genommen und konstruktiv angegangen.	☐	☐	☐	☐
g)	Im Rahmen meiner Tätigkeit erlebe ich Zeitdruck.	☐	☐	☐	☐
h)	Die Arbeitsbedingungen fördern die kollegiale Zusammenarbeit.	☐	☐	☐	☐
i)	Ich kann meine Arbeitsbedingungen beeinflussen, wie z.B. durch flexible Arbeitszeiten und Aufgabeverteilung.	☐	☐	☐	☐
19.	Wie stark beeinträchtigen folgende Faktoren Ihren Arbeitsalltag?				
		Sehr Stark	Stark	Selten	Gar nicht
a)	Licht, Platz und Raumbedingungen im Lehrerzimmer	☐	☐	☐	☐
b)	Klimatische Bedingungen im Lehrerzimmer	☐	☐	☐	☐
c)	Umgang mit Integration und Inklusion	☐	☐	☐	☐
d)	Klassenraumknappheit	☐	☐	☐	☐
e)	Kurzfristige Änderung der Lehrpläne	☐	☐	☐	☐
f)	Krankmeldungen im Kollegium	☐	☐	☐	☐

Vielen Dank für Ihre Unterstützung!

Annexure II: Declaration

DECLARATION

I hereby declare that this dissertation entitled **"Assessment of Indoor Air Quality in Classrooms and Wellbeing of Teachers in Schools of Hamburg, Germany"** is a bona fide work carried out independently by me under the guidance of **Prof. Dr. Walter Leal,** and **Dr. Amena Ahmad**. I have explicitly cited all material which has been quoted either literally or by content from the used source.

Date:**08.08.2018** **Preeti Vishnani**

Place: **Hamburg**