INDOOR ENVIRONMENTAL QUALITY & STUDENT HEALTH AND PERFORMANCE: A CONCEPTUAL REVIEW

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Abstract

The paper discusses reviewed literature on the aspects important for classroom Indoor Environment. A variety of classroom conditions were seen detrimental to health and performance of children and adolescents. Several researches revealed significant co-relation between condition of the school building and students learning and performance. Indoor environments in schools were claimed to cause health effects that directly impair concentration or memory – e.g., neurological effects – or cause other health effects that indirectly affect learning – e.g., poor concentration, dizziness etc. Indoor Environmental Quality (IEQ) factors such as exposure to nature and daylight, air quality, temperature, odors, noise, ergonomics, and humidity affect well being and performance of its occupants. The most documented IEQ risk factors were indoor temperature and ventilation/indoor air quality. Analysis of research also showed these factors to be commonly outside the recommended ranges (lighting – 40 to 50 fc and ventilation rate of 8 L/s per person) in school buildings. It was seen that the average CO_2 levels in classrooms often exceed the limit of 1500 ppm and ventilation rates were often below the minimum requirement of 3 L/s per person.

Key words: Indoor Environmental Quality, Health, Performance, Learning, Indoor Air Quality, Temperature, Ventilation**,** Lighting

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Introduction:

The research studies conducted worldwide, reviewed in this paper, indicate that there is a large untapped potential to enhance student health and performance by improving the Indoor Environmental Quality (IEQ) of schools. It is evident that children and adolescents spend a considerable amount of time indoors, i.e., about 90%, either in school buildings or at home. Within a School also, classroom is the most important area where students spend most of their time. A variety of conditions exist in classrooms that can be detrimental to their health. The available research data proved that by providing better School IEQ, one can improve student learning which, in turn, would lead to more effective future workforces. Numerous research studies indicate that students in functional or acceptable buildings perform better than the students in poor buildings. Studies also claim lower percentile rank points of students in poor buildings as much as 5 to 10 points than students in functional buildings, after controlling socioeconomic status. Indoor environments in schools might cause health effects that directly impair concentration or memory – e.g., neurological effects – or cause other health effects that indirectly affect learning – e.g., poor concentration, dizziness etc. For instance, indoor pollutants might exacerbate diseases such as asthma or allergy that produce symptoms or absenteeism that in turn impair learning, or lead to use of medications that can impair performance. Maintaining an acceptable IEQ is of utmost importance in places such as schools, colleges and university campuses. Therefore, the need was felt to conduct the conceptual review of the current scientific evidences linking school IEQ and health & performance of students. The research paper has tried to present the gist of existing body of knowledge in the area of IEQ in schools and classrooms and their relationship with student health, and performance. The paper focuses on the selected aspects of indoor environments (viz., lighting, indoor air quality and temperature) and their impact on academic performance of students, their health and well being.

Methods used in Research Studies: This paper is based on a review and analysis of the published scientific literature addressing the linkages of IEQ with health and performance of students. The original scientific researches employed a variety of study designs. Some of the research employed cross-sectional multi-building surveys of IEQ conditions and health, absence, or work performance outcomes. These studies used statistical models to analyze the resulting data and quantify the effect of specific factors, such as air quality and ventilation rates, on outcomes (e.g., absence rates, test scores etc.), controlling other factors that also influence the

outcome (e.g., student age and socioeconomic status). Other research has experimentally modified IEQ factors (e.g., temperature or ventilation rate) in real buildings and measured the resulting health or performance changes. In few other studies additional data to assess existing specific IEQ conditions of schools were examined by on-site-inspections and measurements using appropriate measuring tools.

Indoor Environment:

IEQ is a generic term used to describe the attributes of enclosed space, including the thermal, acoustic and visual environment, as well as indoor air quality (IAQ). Both physical (measurable) and perceptual (human comfort) factors play an important role in defining IEQ. The building's IEQ have an influence on health, well being and comfort of building occupants, which in turn may impact their productivity at work (Paevere et al., 2008). The components of IEQ can be divided into -

- Indoor air quality (IAQ)
- Ventilation Rate (fresh air intake, recirculation, exhaust)
- Thermal comfort (temperature, radiant heat, relative humidity, draftiness)
- Acoustic environmental quality (the levels and kinds, classroom acoustics, inside and outside sources)
- Luminous and visual environmental quality (amount and quality of light, lack of glare, direct sunlight)
- Interior Wall Color & Paints

IEQ has also been defined as anything of the built environment that impact the health and/or comfort of the building occupants (California Integrated Waste Management Board, 2007). The U.S. Green Building Council (USGBC) in its Leadership in Energy and Environmental Design (LEED) certification criteria has dedicated an entire category to IEQ. It consists of indoor air quality, thermal comfort, acoustics, daylight and views (USGBC, 2002).

However, this paper focuses only on selected important aspects of indoor environments viz., indoor air quality & ventilation, lighting and temperature.

IAQ & Ventilation: IAQ refers to the totality of attributes of indoor air that affect a person's health, well being and comfort. Children, even those without pre-existing illness or chronic conditions, are susceptible to air pollution because their lungs are still developing, and they are often engaged in vigorous activities, making them more sensitive to pollution than healthy

adults. Research studies showed that in children, particulate pollution was proportionately associated with increased episodes of coughing, breathing difficulty and decreased lung function. Researches revealed that poor IAQ in schools and dwellings influences children's health, increases occurrence of respiratory diseases such as asthma, cough, respiratory allergies and other infections, hinders learning ability, reduces teacher and staff productivity (USEPA, 1996). It was also evident that absenteeism can serve as an indicator of student's or teacher's overall health condition, although attendance pattern result from a complex interaction of many other varied factors. J. M. Daisey (2003) and G. A. Heath and M. J. Mendel (2005) in their review study collected and analyzed existing school data on ventilation rates, CO_2 concentration and symptom-relevant indoor air contaminants. In their study it was found that the reported ventilation rates were inadequate and CO_2 concentrations were significantly higher in many classrooms, possibly leading to health symptoms. Asthma and 'Sick Building Syndrome' symptoms were also commonly reported. Shun-Cheng Lee (2002) claimed higher indoor bacteria levels in air-conditioned classrooms in Hong Kong. Denise M. Hreha (USA, 2007) in her research study found that many variables affect student's achievement and IAQ is found to be one of the important aspects. Venda Hellsing (2009) reported in her comparative study of IAQ in schools in Reykjavik – Iceland, Taiyuan – China and Uppsala – Sweden that the air exchange rate in schools in Reykjavik was not sufficient and the main source of the Ultra Fine Particles and particulate matter were located inside the school. The study also revealed that significant improvement was needed in the ventilation system in schools to reduce UFP, PM and CO_2.

Ventilation is an important aspect of IAQ which is necessary to remove indoor generated pollutants from indoor air or dilute their concentration to acceptable levels. Ventilation includes both the exchange of air to the outside as well as circulation of air within the building. Inadequate ventilation in schools can result in either physiological or psychological illness or disorder in students. The Education (School Premises) Regulations stipulate that ventilation capable of providing at least 8 litres of fresh air per second per occupant is required for all teaching areas. The existing research literature also indicate that ventilation has a significant impact on several important human outcomes including communicable respiratory illnesses; sick building syndrome symptoms; task performance and productivity; perceived air quality (PAQ) among occupants and respiratory allergies & asthma. Reported ventilation and CO_2 data strongly indicate that ventilation is inadequate in many classrooms, possibly leading to health

symptoms (Daisey et al., 2003). Yan Youa et. al. (2007), found out high CO_2 concentrations in indoor environments on campus, which indicated that classroom ventilation rates were often below the minimum rates specified as per their standards. Ulla Haverinen-Shaughnessy et al. (2006) concluded in their study that classroom ventilation rate was significantly associated with math test scores of school students. Zs. Bakó-Biró et.al.(2007), in their study found considerable drop in the CO_2 concentrations when the classrooms were adequately ventilated (Fig.1)

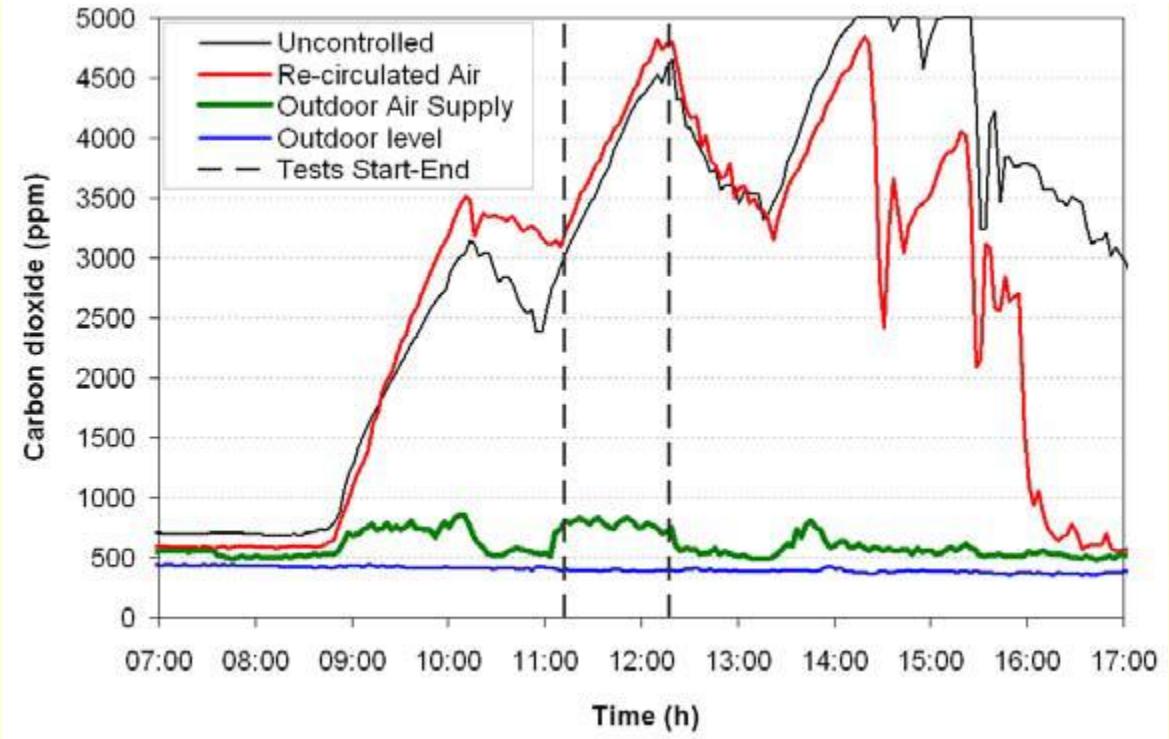

Figure 1: Typical pattern of the CO2 level inside a classroom at different ventilation conditions on a testing day. The uncontrolled condition reflects CO2 concentration during a normal school day without any intervention measures.

Temperature:

Maintaining the right temperature to satisfy everyone in a classroom is probably impossible. However, when exposed to extreme temperature every child in the classroom suffers. In very hot or cold environment, individuals spend more physiological energy to cope with the surroundings. World Health Organization (WHO) recommends a maximum air temperature of 24 ^{o}C (75.2 ^{o}F) for comfortable work. Research has shown that employees simply don't perform well, and attendance suffers, in very hot and very cold workplaces. The indoor temperature affects several

human responses, including thermal comfort, perceived IAQ, sick building syndrome (SBS) symptoms and work performance. The indoor temperature also affects people's productivity (Seppanen et al., 2004). Pepler and Warner (1968) reported, from an experimental study of learning efficiency among adults in a school laboratory, that as temperatures increased from 16.6°C (62°F) to 26.6°C (80 °F), speed of work decreased by 7%. Wyon and Wargocki (2007) also claimed similar results stating that significant effect was seen on student speed on the same tests when temperatures were lowered from 25°C (77°F) to 20°C (68° F). The result reported linear relationship between temperature and student performance, where reducing air temperature by 1.8° F improved student performance in terms of speed by 2% to 4% in all tasks. Schneider (2002) reported in his review study that students would perform mental tasks best in rooms kept at moderate humidity levels (40 to 70%) and moderate temperatures in the range of 20°C (68°F) to 23.3°C (74 °F).

Use of area	Minimum temperature
Lower than normal level of physical activity, eg. Sick Rooms	21 °C
Normal level of physical activity, eg. Classrooms and Libraries	18 °C
Higher than normal levels of physical activity, eg. gyms and drama workshops	15 °C

Figure 2: Minimum standards for temperature

[As prescribed by The Education (School Premises) Regulations 1999 (ATL 2008)]

Lighting: Under the Education (School Premises) Regulations, the illumination of school classroom must be 300 lux or more at any point on the work surface. Researches indicate that controlled day lighting and appropriate artificial lighting improve the performance of students and teachers and their health and well being. Research by Heschong-Mahone Group (1999) supported the relationship between lighting and student test scores and health. Both the presence of sunlight and the types of classroom lighting have been linked to improved student performance (Cash, 1993; Earthman et al, 1995). The National Summit on School Design (2005), in its recommendations, included an emphasis on daylight in learning spaces and energy-

efficient and aesthetically pleasing lighting within the building. Research study by Kennedy (2008) affirmed that daylight is recognized as a valuable parameter for enhanced student performance and as a critical consideration for energy conservation. Numerous studies in office buildings have also found that people value daylight and prefer to be near windows (Heerwagen and Orians, 1986; Collins, 1975). Studies by Roger Ulrich (summarized in Urlich et al, 1991 and Ulrich, 1992) showed that visual contact with nature through window-views enhances mood, reduces stress, and promotes higher quality of life. There are evidences of Visual injury, burning eyes, exhaustion and headaches because of poor lighting in the workplaces [One workplace, 1999]. Light also has very deep physical and psychological effects on humans. Poor lighting has common exhibit on students or other people as well as: red or bloodshot eyes after reading, squirming and fidgeting during reading or close work activities, skipping words or lines while reading or writing. Well designed lighting environment can alleviate eyes' strain, speed up the recognition of things, and increase visual stability or durability.

	General Classroom	Computer Classroom	School Corridor
Light on walls and ceilings	●	●	◐
Control of direct and reflected glare	◐	●	○
Uniformity	◐	●	○
Daylight	●	○	◐
Color rendering and color temperature	◐	●	◐
Lighting controls	●	◐	○
Quantity of light (horizontal footcandles)	40-50 fc	20-40 fc	10 vert. fc

● Very Important ◐ Important ○ Somewhat Important

Figure 3: Optimal Lighting Standards for School Classroom

(Source: "Energy Effective Lighting" for Classrooms: Combining Quality Design and Energy Efficiency)

Conclusion:

The classroom infrastructure and Indoor Environment Quality (IEQ) in majority of schools is found to be poor and below standards to support hygienic and healthy learning environment for students. Though RTE Act 2010 recommends free and compulsory education to all children between 6 to 14 years, there is no emphasis laid on the need of basic infrastructural facilities and

IEQ standards which can significantly affect student's ability to perform specific mental tasks requiring concentration, calculation, or memory. Also, there are not a lot of studies conducted in India to see the effect of IEQ in non-corporate buildings, especially in schools and classrooms, on the performance and well being of students. However, researches from other countries as reviewed in this paper strongly indicate the relationship between improvements in IEQ leading to better performance and well being of students. One such case of renovation, in 1997, of Charles Young Hill Top Academy in the District of Columbia is a classic illustration of how an improved school environment contributed to higher levels of educational performance (Michael, 2002). The analysis of the research studies clearly indicate that school IEQ is significantly related to the student health and performance. Grades of students increase significantly with the improvement of classroom IEQ. The primary goal of this review was to summarize available knowledge relevant to the effects of indoor school environments and the performance and health of children Little direct scientific evidence of high quality was available to relate temperature and student health & performance. Nevertheless, the findings provide suggestive (and some strongly suggestive) evidence that certain conditions commonly found in schools have adverse effects on the health and the academic performance schoolchildren. It was seen that the most documented IEQ risk factors are indoor temperature and ventilation/indoor air quality. Analysis of research also showed these factors to be commonly outside the recommended ranges (lighting – 40 to 50 fc and ventilation rate of 8 L/s per person) in school buildings. It was seen that the average CO_2 levels in classrooms often exceed the limit of 1500 ppm and ventilation rates were often below the minimum requirement of 3 L/s per person. Thus, research findings make a strong case for immediate, targeted actions of prevention and mitigation in school environments. These actions include ensuring, throughout the life of each existing and future school building, adequate outdoor ventilation, maintaining satisfactory IAQ, control of moisture, and avoidance of indoor exposures to microbiologic and chemical substances considered likely to have adverse effects. This paper may prove to be helpful in sensitizing researchers & health professionals in the area of school IEQ. It may help education policy makers in India to formulate and regulate schools to maintain these IEQ standards, thus providing students with productive learning environment. Further, the research study may also help to develop guidelines for maintaining standard IEQ parameters in education institutions.

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