PRODUCTIVITY IN SCHOOLS

Pawel Wargocki
Technical University of Denmark, PAW@BYG.DTU.DK
EFFECTS OF INDOOR CLIMATE (AIR QUALITY) IN SCHOOLS ON LEARNING ABILITIES AND ACADEMIC ACHIEVEMENTS
INDOOR AIR IS SIGNIFICANT CONTRIBUTOR TO LIFE-TIME EXPOSURES
IAQ IN SCHOOLS IS IMPORTANT

- 20% of EU’s population
- 20% of time in schools
- Children must attend school; they cannot absente themselves or find another school
- The work that children are obliged to perform in schools is not optional and almost always new
- Children have far fewer ways of registering complaints
- The effects of IAQ/IEQ on children are likely to be more marked than for adults as children are more vulnerable and their bodies are still growing
SCHOOL ENVIRONMENT IS SPECIAL

- Children (pupils) and adults (teachers and other personnel)
- Occupancy is higher in classrooms than in other buildings (offices/dwellings)
- Teaching is carried out in groups (classes) with low area/volume per person
- There should be as least as possible distraction during teaching
A good education system constitutes one of the fundamentals of a modern society, because poor learning can have lifelong consequences for a student and for society.
The primary purpose of school building is to provide an optimal conditions for learning and then to conserve energy.
VENTILATION REQUIREMENTS IN SCHOOLS

CO2 concentration (ppm)

Ventilation rate (L/s/person)

Schools

Offices
MEASURED VENTILATION RATES IN EU BUILDINGS

Ventilation rates, L/s per person

- Offices
- Dwellings
- Schools

HEALTHVENT. 2013
Mass Experiment 2014: 59% (Sealand: 64%) >1,000 ppm
WHAT ARE CONSEQUENCES?
SCHOOLWORK (CHILDREN AND TEACHERS)

- Attitudes: cognitive skills
- Academic behaviours: typical school tasks and absence rate
- Academic achievements: standardized tests
- Usually 3rd to 6th grades (9-12 years old)
ATTITUDES: PSYCHOLOGICAL TESTS FOR MEASURING COGNITIVE SKILLS

(simple/choice reaction time, colour-word vigilance)

Myhrvold et al., 1997
• 18 schoolchildren, age 10-11
• 4 test sessions with range of cognitive tasks at CO$_2$ of 690±122 (501-983) ppm and 2909±474 (2096-4140) ppm
• Significant effects (better at lower CO$_2$): simple reaction time, power of attention and (close to significant) digit vigilance reaction time and choice reaction time
• Non significant effects: digit vigilance accuracy and false alarms, choice reaction time accuracy, picture recognition response and accuracy.
• Pupils significantly more calm at high CO$_2$ (self-assessed)
ATTITUDES: PSYCHOLOGICAL TESTS FOR MEASURING COGNITIVE SKILLS -2
(reaction time, colour-word vigilance, memory, recognition)

Bako-Biro et al., 2011

$\text{CO}_2 = 3,050 \text{ ppm}$

$\text{CO}_2 = 925 \text{ ppm}$

(1 L/sp vs 8 L/sp)
ATTITUDES: PSYCHOLOGICAL TESTS FOR MEASURING COGNITIVE SKILLS
(d2-test for concentration)

\[ \text{CO}_2 = 3,800 \text{ ppm} \quad \text{CO}_2 = 870 \text{ ppm} \]
Cognitive skills are affected by poor classroom air quality

- Reaction time
- Memory
- Concentration
- Attention

*Important component skills securing proper education progress*
ACADEMIC BEHAVIOURS: EFFECTS FOR TYPICAL SCHOOL TASKS
(math & language based)

Performance (speed)

Outdoor air supply rate (L/s/person)

Wargocki et al., 2012
1-1.5% reduction in absence rate per 1 L/sp
CO₂, SCHOOL ATTENDANCE, EDUCATIONAL ATTAINMENT

- 60 classrooms in 32 primary schools in Aberdeen
- Each school 2 classrooms (6-7 and 10-11 years old)
- 1 week measurements of CO₂ (temp rh) in early summer months: median 1086 ppm IQR 922-1310 ppm
- Absence rates for the whole school year
- Educational attainment (% of class attaining the average level expected for this group)
- Models adjusted for socioeconomic indicators (free school meals)
- **An increase of 100 ppm corresponded to 0.2% increase in absence rates** (0.04-0.4) corresponding roughly to ½ day a year (in 190 days school year); average absence rate in Scotish schools 5.1%
- No effects on attainment
% of students who passed the test

Outdoor air supply rate

% of students who passed the test

Outdoor air supply rate

Haverinen-Shaughnessy et al., 2013
NATIONAL STANDARD EDUCATIONAL TESTS
(math, language-based, science (chemistry/physics, geography, biology), foreign language)

Adjusted national test result (%)

- Mechanical balanced
- Exhaust
- Natural (airing by windows)

Indblæsning og udsugning (n=81)
Kun udsugning (n=31)
Naturlig ventilation (n=146)

(P<0.008)

Uldahl Kjeldsen et al., 2013
OECD: COUNTRIES WITH BETTER TEST SCHOOL RESULTS HAVE HIGHER GROWTH RATE

The OECD new survey of Adults Skills finds that foundation skills in mathematics have a major impact on individual’s life chances. The survey shows that poor mathematics skills severely limit people’s access to better-paying and more rewarding jobs; at the aggregate level, inequality in the distribution of mathematics skills across populations is closely related to how wealth is shared within nations. Beyond that, the survey shows that people with strong skills in mathematics are also more likely to volunteer, see themselves as actors rather than objects of political processes, and are even more likely to trust others.
1 L/s per pupil higher ventilation rate:
* About 3% higher performance of schoolwork
* About 1.5% lower absence rates
HOW ABOUT OTHER INDOOR CLIMATE PARAMETERS?
CLASSROOM TEMPERATURE, PSYCHOLOGICAL TESTS

Bako-Biro et al., 2012

![Graph showing relative performance with different temperatures.](image-url)
CLASSROOM TEMPERATURE, TYPICAL SCHOOL TASKS

Performance

%  120  110  100  90  80  70

18  20  22  24  26 °C

Temperature

8%
(2-4% per 1°C)

Wargocki et al., 2012
HOW ABOUT TEACHERS?
Teachers also perform less well.

Hongisto, 2005; REHVA, Wargocki et al., 2006
VENTILATION REQUIREMENTS IN SCHOOLS

CO2 concentration (ppm)

Ventilation rate (L/s/person)

Schools

Offices
VENTILATION REQUIREMENTS IN SCHOOLS

CO2 concentration (ppm)

Ventilation rate (L/s/person)

Schools

Offices
VENTILATION REQUIREMENTS IN SCHOOLS

CO2 concentration (ppm)

Ventilation rate (L/s/person)

Schools and Offices
“It is certain that the additional expenses per pupil of the best ventilation needed not exceed the price of one or two cheap lunches.”

New Hampshire School District Ventilation Code, 1893
CONSEQUENCES

- 15% reduced performance (1/8) => 1 school year
- More time for teaching to reach the same educational targets, teacher cost => compare with the renovation costs
- Absence rates of pupils (& care takers) and teachers => cost of absenteeism
- Loss of opportunity (salary) as regards future work => socio-economic impact
- Consequences for national economy => GDP and public expenses/incomes
SOCIO-ECONOMIC CONSEQUENCES

OECD 2010: countries with better test school results have higher growth rate
SUMMARY REMARKS
ENERGY IS A LOW HANGING FRUIT

Source: independentresidentialenergy.com
PURPOSE OF THE SCHOOL

- Buildings are not constructed to save energy
- They must first promote health together with energy and sustainability, health is included in the sustainability concept
- The primary purpose of school building is to provide an optimal conditions for learning and then to conserve energy
- IEQ in classrooms plays an important role in learning process, probably as important as teaching materials and methods
- High IEQ should become an urgent educational priority
QUESTIONS?