

Productivity and schools

IA2008 Summary

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Summary

- 3 technical sessions
 - Mo10T2: Productivity
 - Th13T5: IEQ in schools
 - TH15T5: Ventilation of school classrooms
 - Tu15T1: Thermal comfort responses
- 2 forums
 - Mo13F8: Effects of IEQ on performance – The need for future research
 - Th17F6: Strategic IEQ improvement for schools
- 40 papers (5%)

Performance of office work, single factors

- Laboratory experiments with simulated office work
- Significant effects of increased ventilation rate (improved IAQ) on performance (up to 20%)
- No significant effects of thermal discomfort on performance but significant effects on general symptoms
- No effects of drifting temperature on performance but significant effects on general symptoms
- Increased temperature may affect short term memory (easy questions) and long-term memory (medium difficult questions)

Performance of office work, combined factors

- Laboratory experiments
- Temperature and ventilation:
 - Office work performed less well the lower subjectively rated indoor environment
- Office noise and temperature:
 - only noise affected performance of simulated office work
 - increased temperature increased intensity of general symptoms even more with noise present
- Traffic noise, temperature and air quality:
 - noise increased anxiety and stress while increased temperature increased anxiety
 - no interaction between factors
 - noise dominated the effects on anxiety and stress
 - IAQ and temperature particularly important in noisy environments

Possible mechanisms by which IEQ affects the performance

- Increased thermal discomfort cause the increase in mental demand and subjective effort to maintain performance
- The higher hemoglobin levels in brain (cerebral blood flow measurements) the higher mental work load
- Increased temperature results in increased complaints of fatigue
- The higher dissatisfaction with air quality the higher fatigue
- The higher temperature swings the higher fatigue.
- The higher satisfaction with the environment and the lower fatigue the higher performance
- The gaseous pollutants rather than particles reduce the performance of schoolwork

Methods & predictors of the effects of IEQ on performance

- Self-estimated performance, depending on how you ask the question
- Fatigue and satisfaction better predictors of performance
- Cerebral blood flow – a mean of determining the cost of overcoming the environmental stress
- Neurobehavioral test

Consequences of reduced performance, modelling

- Providing mesh chairs, desk fans and air conditioning allows the temperatures to be increased from 25 to 28°C (COOLBIZ): cost to benefit 1/340 if performance reduction assumed to be 5%
- ID Build programme: cooling of air from 30 to 25°C will incur energy costs but benefits of increased performance will be 4 times higher

Performance of schoolwork

- Field experiments in actual schools (interventions or cross-sectional)
- Performance measured using embedded tasks simulating schoolwork or standardized math/language tests
- Increased ventilation rate up to 6-8 L/s/p improved performance of schoolwork
- Self-reported health problems had greater effect on performance than self estimated exposure to poor IEQ
- Reduced particle concentrations outside pollen season did not affect performance of schoolwork

It is hard to be a child....

- CO₂ levels in naturally ventilated classrooms up to 5,000 ppm (Italy, China, UK, USA)
- Large spatial variation in CO₂ levels
- Human odors most dominating
- BTEX levels high in naturally ventilated classrooms
- Noise levels in classrooms up to 20 dB(A) higher when windows opened (Korea)
- Symptoms of fatigue, absence of mind, headaches, dry skin, draughts, unpleasant odors and too low temperatures prevalent

The good news....

- Radon levels in schools are decreasing mainly because ventilation is increased (Sweden)

Not all solutions work....

- Sustainable school design with hybrid ventilation reduce energy use for ventilation by 15% but has no additional positive effect on IAQ
- Hydronic Radiant Heating Systems do not improve thermal comfort compared with traditional systems
- Provision of cooling systems reduce temperature but reduce IAQ as air change rates are significantly reduced compared with cross-ventilation
- Operable windows do not guarantee improved classroom IAQ
- Natural ventilation can not achieve thermal and air quality requirements with high internal thermal even at outdoor temperatures of 5°C

Not all solutions work....

- An excessive noise absorption in open-plan offices may have a negative impact on occupants' perception of noise, the acceptability of noise and the performance of office work; background noise may be beneficial

What does work?

- Cross-ventilation with proper windows/doors opening – up to 2 h^{-1} even with temperatures up to 14°C and wind speed down to 1 m/s
- Fan-assisted natural ventilation
- Mechanical ventilation, displacement ventilation
- Diffuse ceiling ventilation (perforated ceiling), flows up to 11 L/s/p , $\Delta t=18\text{K}$, low fan energy and low noise

The cost can be high...

- Forecast of energy use due to installation of air-conditioners in Japan suggests 54% increase by 2030 (100% schools have AC); the following measures are suggested to keep the energy low: natural ventilation, use of heat exchangers, lowE-glass, window roof and 15% increase in efficiency of air conditioners
- To reduce temperatures (without cooling) in Nordic countries below 25°C ventilation rates should be at least 10 L/s/p, supply temp. down to 14°C and demand controlled ventilation; in summer the night ventilation is needed

What was missing?

- No studies on the performance of office work in field, thus no information on differences between simulated work and real work
- No studies on the effects on complicated work (creative work)
- No systematic data on short-term and long-term effects
- Only few studies explaining possible mechanisms behind the observed effects, but still no information on e.g. which pollutants are important

Challenge....

- To which extent are suboptimal working conditions economically justified?
- How much energy can be conserved in buildings before it begins affect the national economy?