The effect of indoor air quality in Dutch higher education classrooms on students’ health and performance

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Aim of study

• Developing and testing a questionnaire for measuring perceived indoor environmental conditions in classrooms for higher education
• To increase the awareness about the indoor environment among students, by measuring actual indoor environmental conditions
• To understand how students perceive the actual classroom conditions
• To share the gained knowledge
Context of study

- Teachers and students need good learning environments to perform well \(^1\)
- Indoor air quality (IAQ), thermal conditions, acoustic conditions, and visual conditions may be extremely powerful in order to support the in-class tasks of teachers and students \(^1,2,3\)
- Adequate ventilation and thermal neutral conditions in classrooms could improve academic performance of students \(^1,4,5\)

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2. Dawson CG, Parker DR. A descriptive analysis of the perspectives of Neville high school’s teachers regarding the school’s renovation. 1998.
Hypothesis

PhD research project:

*Developing guidelines for an optimal indoor climate in classrooms for user-interactions in higher education*

A collaboration between Hanze University of Applied Sciences Groningen and Eindhoven University of Technology, Netherlands
Study design

Actual indoor environment
- indoor air quality
- thermal, visual, acoustic conditions

Perceived indoor environmental conditions
- perceived indoor air quality
- perceived thermal, visual, acoustic comfort
- sick building syndrome

Effect indoor environment on comfort and health
Actual indoor environmental conditions in classroom

- Four school buildings for higher education in the northern part of the Netherlands, age between +/- 10 and +/- 30 years old

Retrieved from http://ontheworldmap.com/europe/
Actual indoor environmental conditions in classroom

- Heating season, period March till April 2019
- ‘In situ’ measurements in 59 classrooms
- Student researchers visited lectures for a duration of 45 minutes
- Three observations during the lecture (beginning, middle, end)
- A minimum of three measurements per classroom
- Average values calculated for the environmental parameters
  - Outdoor ($T_o$) and indoor air temperature ($T_a$)
  - Indoor ($R_{Hi}$) and outdoor relative humidity ($R_{Ho}$)
  - Carbon dioxide concentration ($CO_2$)
Perceived indoor air quality (PIAQ)

- Directly after the lecture students (n=366) filled in the questionnaire using a smartphone or tablet
- Average PIAQ score was calculated
- Health related issues were examined (sick building syndrome)

**PIAQ scale (Cronbach's α 0.8)**

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is some stale air in here *</td>
</tr>
<tr>
<td>There is a lot of fresh air in here</td>
</tr>
<tr>
<td>The classroom is properly ventilated</td>
</tr>
<tr>
<td>The air is stuffy and damp in here *</td>
</tr>
<tr>
<td>The air is dry in here *</td>
</tr>
<tr>
<td>There is a bad smell in here *</td>
</tr>
<tr>
<td>The air is dusty in here *</td>
</tr>
</tbody>
</table>

**Example question perceived indoor air quality**

The air is stuffy and damp in here

* totally disagree  -  totally agree*

1 2 3 4 5

* Answers are reversed for Cronbach's Alpha analyses and PIAQ score
Analyses of the relation between the actual and the perceived indoor air quality

Actual indoor environment
- indoor air quality
- thermal conditions

Perceived indoor environmental conditions
- perceived indoor air quality
- perceived thermal comfort
- sick building syndrome

Effect indoor air quality on comfort and health
### Results (1)

<table>
<thead>
<tr>
<th>Concentration CO₂ (in ppm)</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;800</td>
<td>26.5</td>
<td>18.6</td>
<td>18.6</td>
</tr>
<tr>
<td>800-949</td>
<td>18.6</td>
<td></td>
<td>23.5</td>
</tr>
<tr>
<td>950-1199</td>
<td></td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>&gt;=1200</td>
<td></td>
<td></td>
<td>44.6</td>
</tr>
</tbody>
</table>

1 Rijksdienst voor Ondernemend Nederland, Programma van Eisen Frisse Scholen 2015
Results (2)

Mean scale perceived indoor air quality (PIAQ) in relation to CO₂ concentration

(p<0.01, Pearson -.189)
## Results (3)

Relation between self-reported symptoms (will disappear after leaving the classroom) and perceived indoor air quality (PIAQ)

<table>
<thead>
<tr>
<th>PIAQ Pearson Correlation (*p ≤ 0.05)</th>
<th>dry skin</th>
<th>tiredness</th>
<th>concentration problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-.237*</td>
<td>-.270*</td>
<td>-.291*</td>
</tr>
</tbody>
</table>
Discussion

- Correlation between air temperature ($T_a$), indoor humidity ($R_{H_i}$), and CO$_2$ concentration ($p \leq 0.001$)
- Correlation between PIAQ and perceived thermal comfort
- The self reported symptoms can also be caused by a combination of high indoor air temperatures and CO$_2$ concentration.
Conclusion

When the CO$_2$ concentration in classrooms increases
• perceived indoor air quality declines
• the ability to concentrate decreases
• fatigue increases
• students complain more about dry skin

*Therefore, it affects the quality of learning*
Thank you for your attention / Ačiū už dėmesį

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Acknowledgements

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Do you have any questions

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