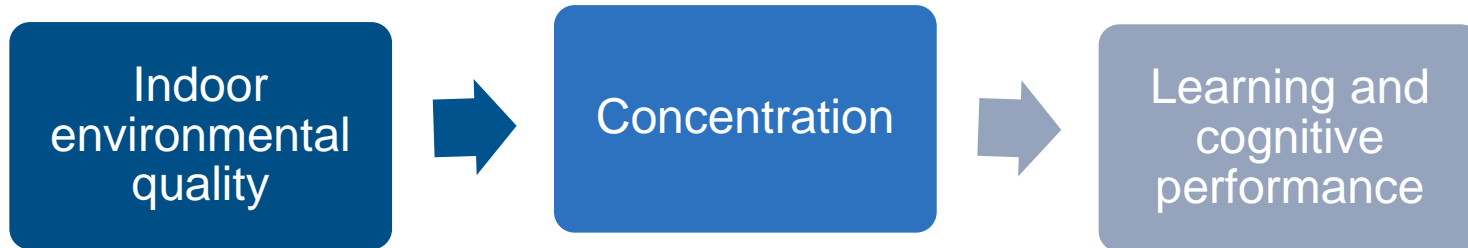# Salla Muuraiskangas

- Master of Health Science,
- Wellness technology, University of Oulu
- Over 12 years of research experience
- developing and testing assistive technologies, health behaviour change systems, motivational strategies etc.

Background for the study

- Concentration is essential for learning and performing school tasks.
- Concentration and cognitive performance is affected by different environmental factors
  - thermal conditions, pollutants such as VOC, particles, and CO_2 [1,2]
- No long-term research on the effects of indoor environmental quality (IEQ) on concentration in real environments using objective measurements.

| Indoor environmental quality | → | Concentration | → | Learning and cognitive performance |

1. T. Salthammer et al., "Children's well-being at schools: Impact of climatic conditions and air pollution," Environ. Int., vol. 94, pp. 196–210, 2016.
2. P. Wargocki and D.P. Wyon, "Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork," Build. Environ., vol. 112, pp. 359–366, 2017.
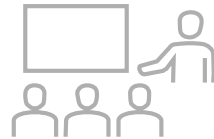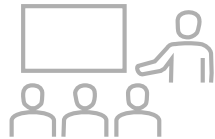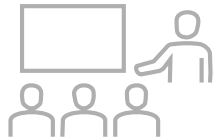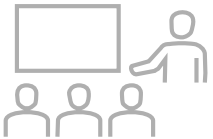
Objective

To study associations between objective IEQ parameters and pupil concentration in an uncontrolled, real learning environment.
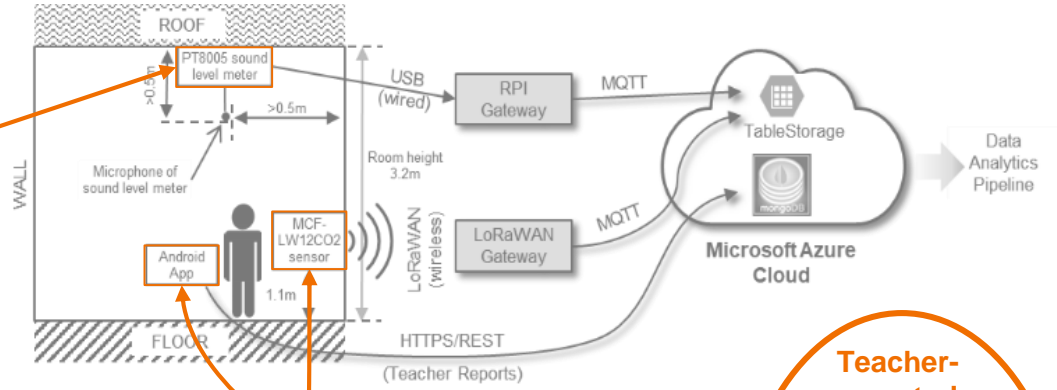
VTT

Methods

- Pilot study
- Location:　　school in Northern Finland
- Duration:　　18 weeks
- Time:　　　　autumn in 2018
- Participants
  - 4 teachers (=4 classrooms)
  - 83 pupils

Data collection

Sound level [1]
1/5s

CO₂, Temperature, Relative humidity, Ambient lighting, IAQ Index [2]
1/15min

Teacher-reported pupil concentration
(by VTT)
1/day

Pupil concentration [3]
2/week

ROOF

PT8005 sound level meter

>0.5

USB (wired)

RPI Gateway

MQTT

TableStorage

Data Analytics Pipeline

WALL

Microphone of sound level meter

>0.5m

Room height 3.2m

MCF-LW12CO2 sensor

LoRaWAN (wireless)

LoRaWAN Gateway

MQTT

mongoDB

Android App

1.1m

Microsoft Azure Cloud

FLOOR

HTTPS/REST
(Teacher Reports)

SELF-REPORTING TOOL

REPORT HERE

Todays surveys
Morning questionnaire
Afternoon questionnaire   13:00

GIVE FEEDBACK

1. https://www.peaktech.de/productdetail/kategorie/schallpegelmessgeraete/produkt/p-8005.html
2. https://www.mcf88.it/prodotto/mcf-lw12co2/
3. J. Liukkonen, "Psyykkinen vahvuus–Mielen taitojen harjoituskirja" (Eng. Psychological resilience- Training book for mind). Jyväskylä, Finland: PS-kustannus, 2017.

Data pre-processing

- **IEQ**
  - average for the IEQ parameters over a 45-minute time span before the concentration test

- **Pupil concentration**
  - median of the score for the whole class
  - more resistant to extreme outliers (some 0 and 100 results among the tests)

- **Teacher-reported pupil concentration**
  - no preprocessing

Classroom differences:
Is it possible to combine room data?

	Room 1	Room 2	Room 3	Room 4	P-values
CO₂ (ppm)	658	600	580	629	0.001
Relative humidity (%)	32	37	31	32	0.381
Ambient lighting (lx)	433	124	204	343	<0.001
Temperature (°C)	21.8	20.9	21.5	21.2	<0.001
Sound level (dB)	56	57	58	63	<0.001
IAQ Index	175	192	237	226	<0.001
Pupil concentration	22	19	24	24	<0.001
Teacher-reported pupil concentration	3	3	3	3	0.077

Not combinable

- Kruskal-Wallis test (non-parametric, data not normally distributed)
  - → assessing whether the data acts too differently between the classrooms
- statistically significant difference (in medians) in most parameters

  → **not possible to combine data from different classrooms**

Correlations between IEQ and pupil concentration: Did the IEQ have effect on pupil concentration?

- Calculated Spearman correlations (non-parametric) → assessing the association between the IEQ and pupil concentration

- Consistent negative correlation between the **relative humidity** and **pupil concentration**
  - Dry indoor and better pupil concentration are associated

	Room 1	Room 2	Room 3	Room 4
CO_2 (ppm)				
ρ	0.493*	0.274	0.491*	0.162
Sig. (2-tailed)	0.012	0.185	0.011	0.410
N	25	25	26	28
Relative humidity (%)				
ρ	-0.620**	-0.728**	-0.568**	-0.706**
Sig. (2-tailed)	0.001	P<0.001	0.002	P<0.001
N	25	25	26	28
Ambient lighting (lx)				
ρ	-0.335	-0.116	-0.468*	-0.147
Sig. (2-tailed)	0.101	0.582	0.016	0.454
N	25	25	26	28
Temperature (°C)				
ρ	-0.374	-0.642**	0.082	-0.199
Sig. (2-tailed)	0.065	0.001	0.690	0.311
N	25	25	26	28
Sound level (dB)				
ρ	-0.052	0.460*	0.324	0.103
Sig. (2-tailed)	0.787	0.014	0.092	0.582
N	30	28	28	31
IAQ Index				
ρ	0.253	0.223	-0.062	0.215
Sig. (2-tailed)	0.222	0.284	0.763	0.271
N	25	25	26	28
Teacher-reported pupil concentration				
ρ	-0.315	-0.182	0.112	-0.197
Sig. (2-tailed)	0.153	0.385	0.603	0.298
N	22	25	24	30

Quick glance at data

- Pupil concentration increasing throughout the pilot
- Relative humidity decreasing throughout the pilot
- Relative humidity at times outside target range (30-40%)

	Room 1	Room 2	Room 3	Room 4	P-values
Relative humidity (%)					
Min	20	22	19	20	
Max	58	59	56	59	
Median	32	37	31	32	0.381
IQR	27-37	29-42	26-39	25-42	
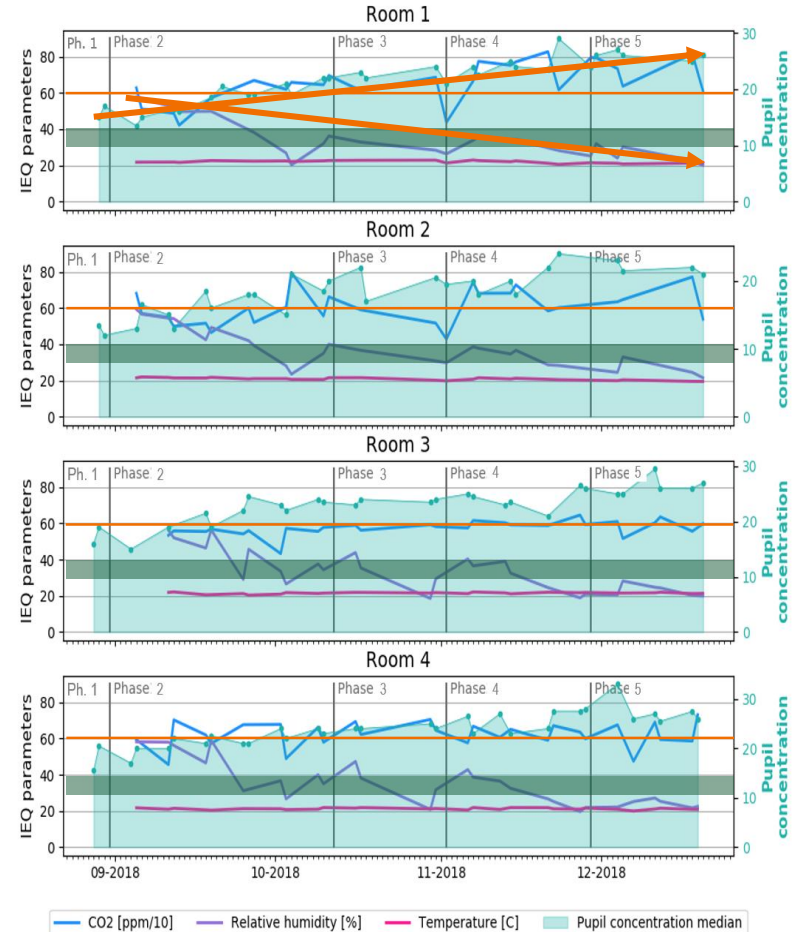
CO2 [ppm/10] — Relative humidity [%] — Temperature [C] — Pupil concentration median

Correlations between IEQ and pupil concentration: Did the IEQ have effect on pupil concentration?

- **No other consistent and strong relationships**

- Some significant discrete correlations
  - Positive correlation with **CO_2** in 2 rooms
    - Not in line with earlier studies[10,11,12]
  - Negative correlation with **ambient lighting** in room 3
    - effects of diurnal daylight variation and human vigilance variation
    - Note: MCF sensor not positioned optimally for lighting
  - Negative correlation with **temperature** in room 2
    - In line with earlier studies[8]
  - Positive correlation with the **sound level** in room 2
    - Rather interesting finding, the voice levels generally high

- No significant correlation between the measured pupil concentration and teacher-reported pupil concentration
  - Teacher reports (scale 1 to 5) are not good way of measuring pupil concentration

	Room 1	Room 2	Room 3	Room 4
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8. P. Wargocki and D.P. Wyon, "Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork," Build. Environ., vol. 112, pp. 359–366, 2017.

10. P. Wargocki and D. Wyon, "The effects of moderately raised classroom temperatures and classroom ventilation rate on the performance of schoolwork by children (RP-1257)," HVAC&R Res., vol. 13, pp. 193–220, 2007.

11. Z. Bakó-Biró, D.J. Clements-Croome, N. Kochhar, H.B. Awbi, and M.J. Williams, "Ventilation rates in schools and pupils' performance," Build. Environ., vol. 48, pp. 215–223, 2012.

12. U. Haverinen-Shaughnessy and R.J. Shaughnessy, "Effects of classroom ventilation rate and temperature on students' test scores," PLoS One 10, e0136165, 2015. Available at: https://doi.org/10.1371/journal.pone.0136165.

Discussion – Limitations and future suggestions

- MCF sensor had low sampling rate, every 15 min → more frequent sampling preferred
  - A single exceptional value can distort the average in the 45 minutes epoch
- Not enough samples to get significant results at these correlation levels → longer pilot (and/or more frequent tests)
  - If the correlation around 0.3 and a power of 0.75 → 38-week pilot when concentration test 2/week → one school year
  - changes in meteorological conditions and the building heating season affect indoor conditions → favors a **full-year measurement**
- Paper-format concentration tests easy to administer but laborious to digitize → test in mobile device would give results right away in digital form
  - reducing the chance of mistakes both in digitization, performing the test

Conclusion

A statistically significant inverse association was found between pupil concentration and the relative humidity in all four classrooms, but no consistent associations with other indoor environmental quality parameters were found.