Technische Hochschule Nürnberg

Ventilation concepts in classrooms: Results of a long-term study in three elementary schools

Susanna Bordin M.Sc.

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Motivation

too cold?

too warm?

feeling sick?

tired?

stuffy air?

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Compare the influence of different ventilation concepts on good air in classrooms

- **Good indoor air quality** (low CO_2 levels)
- Increased **well-being** and **thermal comfort**
- **Reduction** of airborne **diseases**
- **Energy efficient**

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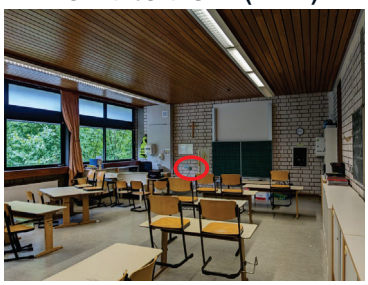
Study design – 3 ventilation concepts

natural ventilation (**NV**)

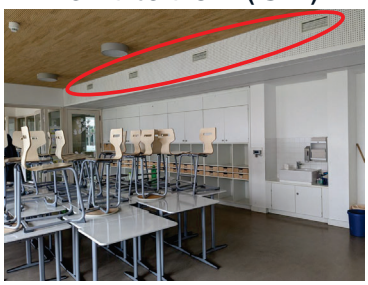


4 classrooms

decentralized ventilation (**DV**)

2 classrooms

central ventilation (**CV**)



2 classrooms

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Observational field study from October 23 – April 24

Influence on:

children (aged 7-11)  questionnaires & saliva samples

physical parameters  long-term monitoring

energy demand  simulations

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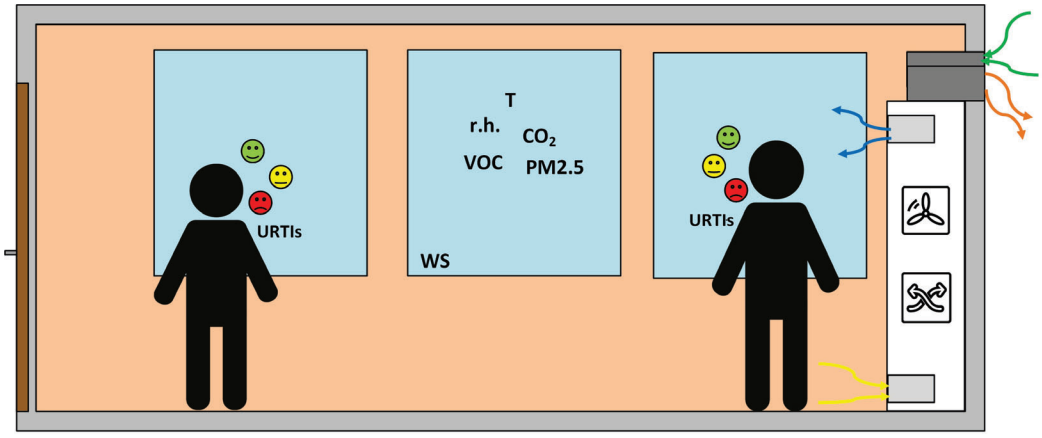
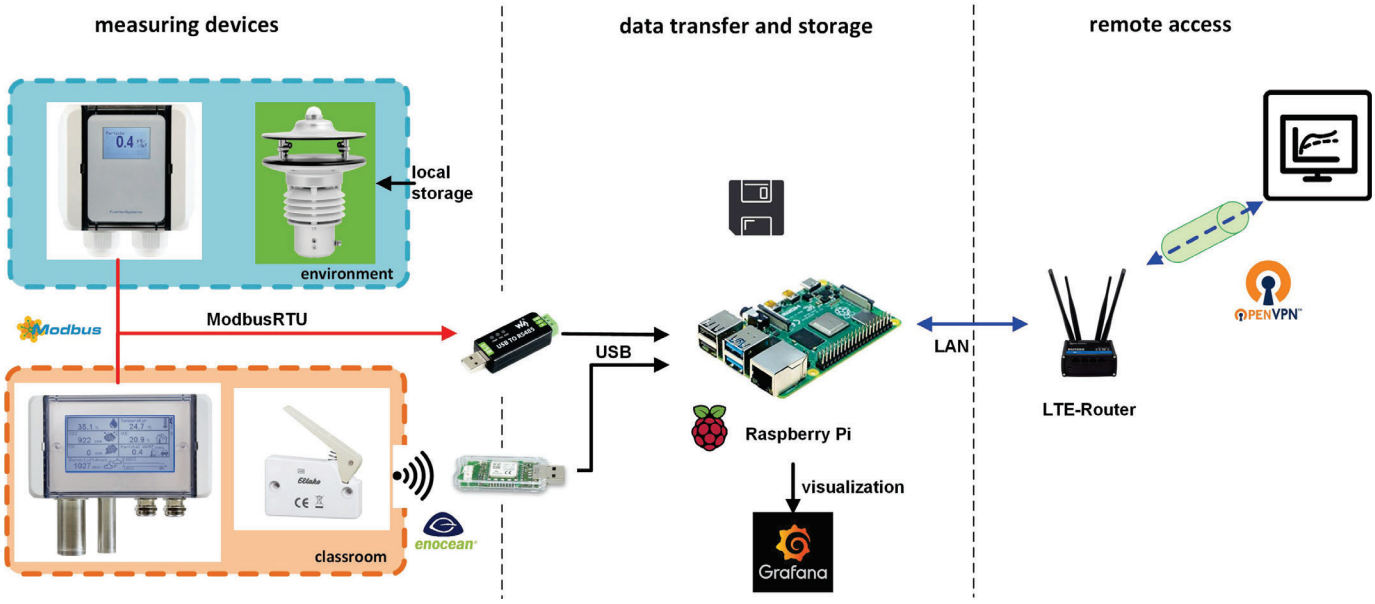
Measured parameters in the classrooms



T:	Temperature	Decentralized Ventilation System	
r.h.:	Relative humidty	Green :	Outdoor Air
CO_2:	CO_2 concentration	Blue:	Supply Air
VOC:	Volatile organic compounds	Yellow:	Return air
PM2.5:	Particulate matter	Orange:	Exhaust Air
WS:	Window status		
🙂:	Well-being and comfort		
URTIs:	Upper Respiratory Tract Infections		

Monitoring concept



Collected data

Timestep: 1 minute

Entire study period: 7 month → 213 days → **120 school days**

- weekends + vacations + public holidays: 93 days

Occupancy time: 8 a.m. -1 p.m. → 6 school hours/day + school breaks

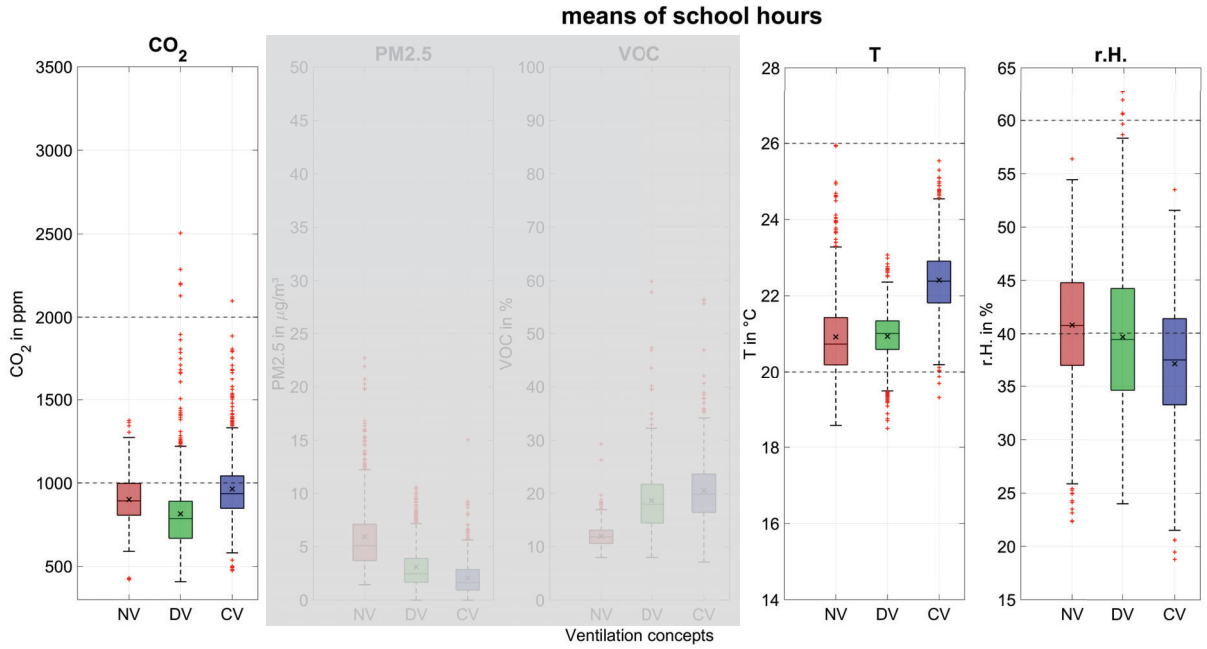
→ **720 school hours (a 45 min)**

Results indoor parameters

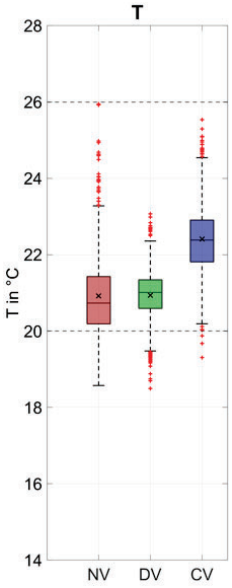
- CO_2
- Indoor air temperature
- Relative humidity

- Window opening times

Entire study period

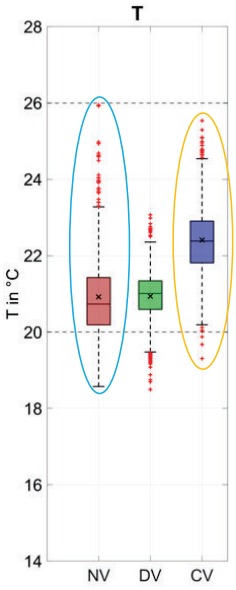


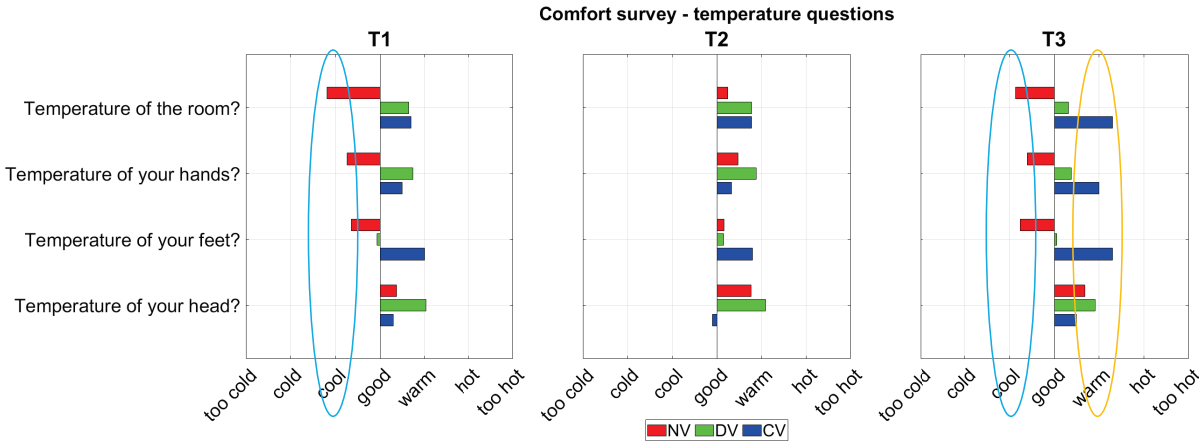
Indoor air temperature



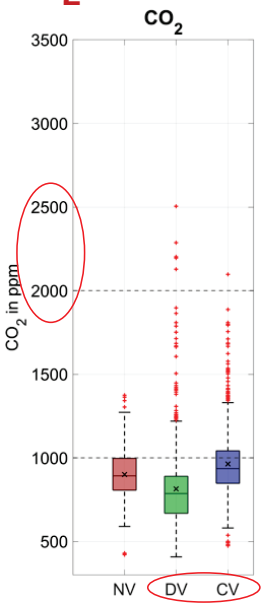
Concept	T < 20 °C	
NV	18.9%	Lowest temperatures & largest temperature spread
DV	10.7%	Smallest temperature spread
CV	0.4%	Warmer temperatures

Temperature – Comfort survey





CO_2 concentration



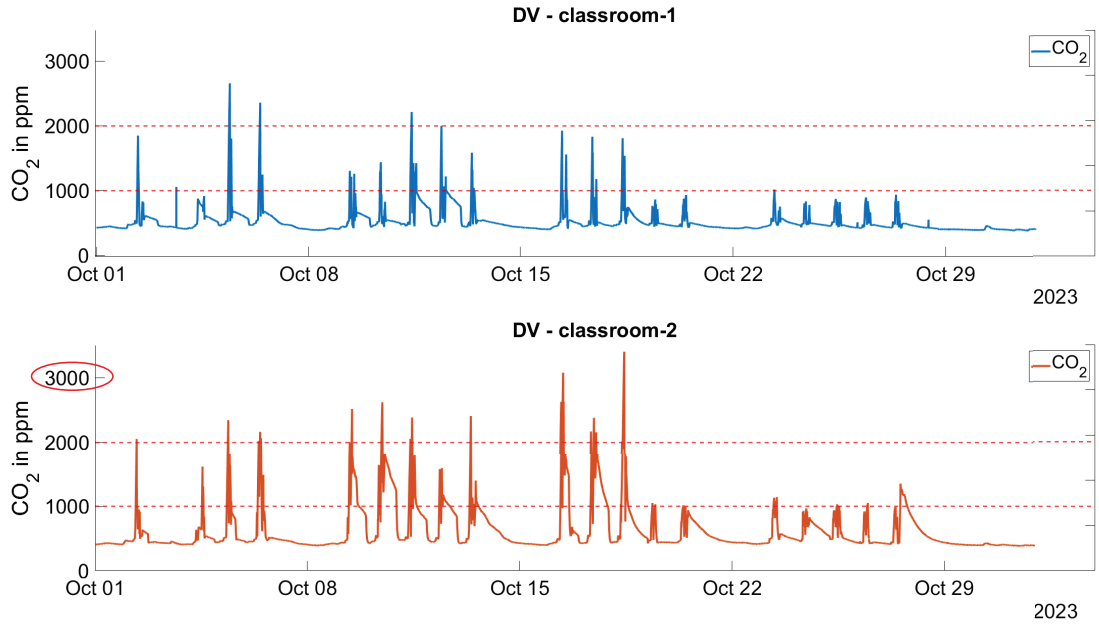
Concept	CO_2 > 1000 ppm
NV	24.7%
DV	10.6%
CV	34.3%

Good to acceptable values

Overall best CO_2 levels, however high outliers!

High CO_2 levels and high outliers!

DV – 2023-10 – CO_2



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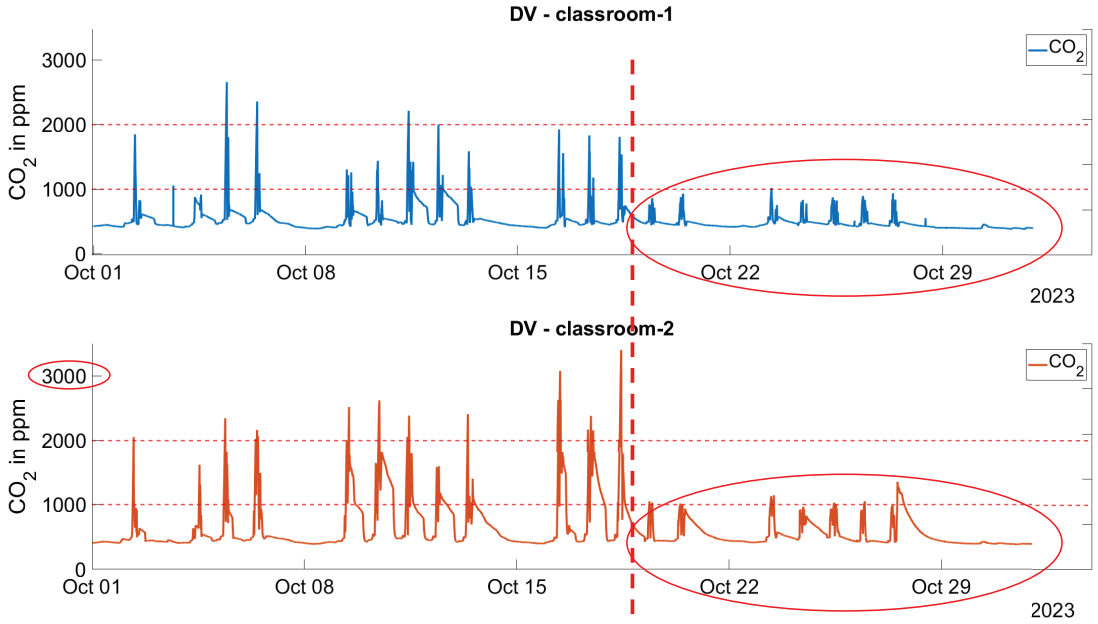
DV – 2023-10 – CO_2



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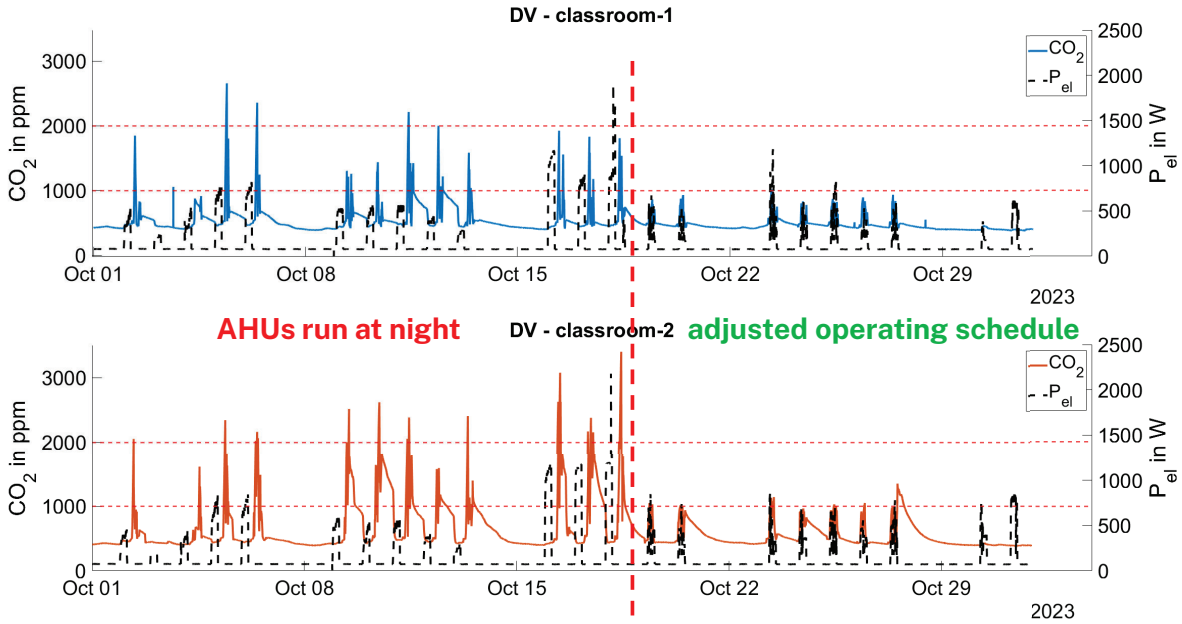
DV – 2023-10 – CO_2 & electrical power



DV – periods with incorrect time settings

6 periods in which the AHUs do not run completely / at all during lessons from 8 a.m. to 1 p.m.

Reasons:

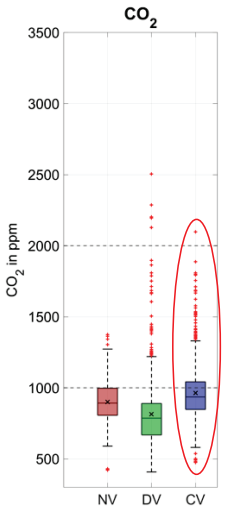
- schedule was set incorrectly
- switching to winter time was 2 weeks too late
- AHUs were switched on too late after vacations or off too early before vacations

CV – CO_2 concentration

Why such high CO_2 levels & peaks?

The supply air is controlled by:

- CO_2 and presence



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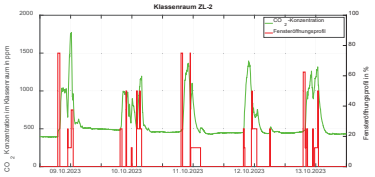
CV – CO_2 concentration

Why such high CO_2 levels & peaks?

The supply air is controlled by:

- CO_2 and presence
- Window state!



monitoring data
& data of building
management system

energy-efficient control strategy:
open/tilted window → supply air is deactivated for this classroom

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Window opening times

Concept	Average ventilation time per school hour
NV	28 min
DV	14 min
CV	11 min

In the NV-group, the windows are opened twice as long as in the mechanically ventilated concepts.

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Window opening times

Concept	Average ventilation time per school hour	Most frequent type of window states
NV	28 min	1 open window (62%)
DV	14 min	1 open window (70%)
CV	11 min	1 tilted window (45%)

In the NV-group, the windows are opened twice as long as in the mechanically ventilated concepts.

In the CV-group, mainly 1 window is tilted during the average ventilation time.

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Summary

- **NV-group**: good to acceptable CO_2 levels
  (big window openings + CO_2 traffic lights),
  however lowest temperatures & widest temperature spread
- **DV-group**: best CO_2 levels
  (correct setting of the AHUs!)
- **CV-group:** CO_2 levels are rather high,
  because of energy-efficient control strategy the users did not know about

- **Relative humidity** is rather low for all concepts, especially for the mechanically ventilated classrooms.

Conclusion

- **Correct setting of ventilation systems is not a matter of course!**

- Decentralized and central ventilation systems
  - must be controlled and operated correctly
  - and the users need to know about “special” control settings.

Outlook

➢Further statistical analysis of the data

➢Finally, combined evaluation of **monitoring results** and **medical results**

Thank you!

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Technische Hochschule Nürnberg Georg Simon Ohm
Susanna Bordin M. Sc.
Institut für Energie und Gebäude (ieg)
E-Mail: susanna.bordin@th-nuernberg.de
phone: + 49 911/5880-3124

Technische Hochschule Nürnberg
ENERGIE CAMPUS NÜRNBERG