

Evidence-Based Interactions between Indoor Environmental Factors and Their Effects on K-12 Student Achievement

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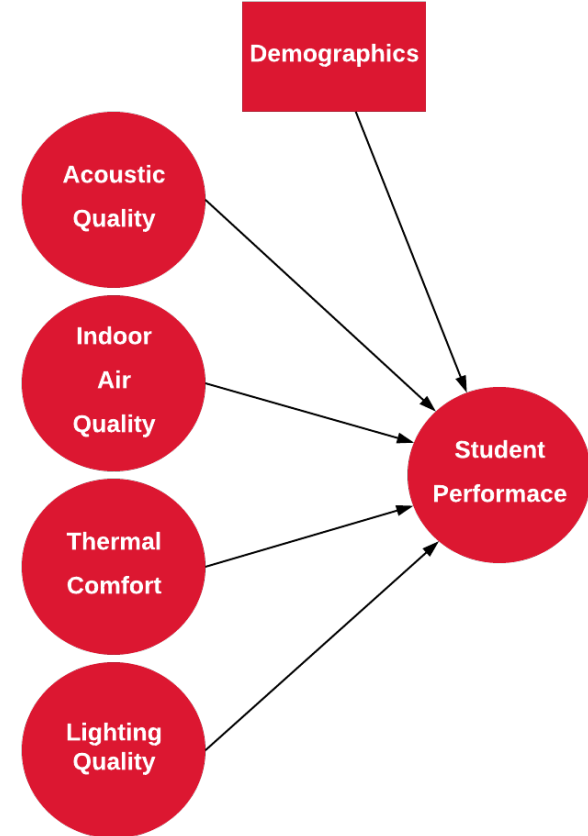
COLLEGE OF ENGINEERING

- “Evidence-Based Interactions between Indoor Environmental Factors and Their Effects on K-12 Student Achievement”



- US Environmental Protection Agency (EPA)
- Period: 11/01/2014 – 10/31/2019

- How do indoor environmental conditions in K-12 school buildings impact students’ academic achievement?



PRIOR WORK		UNL PROJECT
One or two environmental variables at a time		Comprehensive measurements across disciplines
Subjective measures of variables		Objective measurements, many logged in time
Indirect measures of occupant effects		Classroom-aggregated student achievement scores and demographic data
Lack of statistical rigor/effective experiment design		Experts in each discipline, including statistical expert guiding experimental design and analyses



UNL Team: Lau, Waters, Wang and Bovaird



Measurements

- 220 classrooms in 5 local school districts
 - 144 elementary classrooms
 - 32 middle school classrooms
 - 44 high school classrooms
- Occupied Measurements
 - 36 hour logging
 - Repeated 3X seasonally
- Unoccupied Measurements
 - After school dismissal



- Measurement Kit
 - Formaldehyde monitor, Particulate Matter meter, CO₂ meter with Relative Humidity and Globe Temperature, Sound Level Meter, Illuminance meter
- Hanging Sound Level Meter
- CO₂ meters (Supply, Return, Outside)
- Additional Illuminance meters (4)
- Door State loggers (2)



- Room geometry / photos
- Illuminance
- Air velocity
- Indoor air quality probe
- Ozone
- Acoustic impulse responses



Demographics

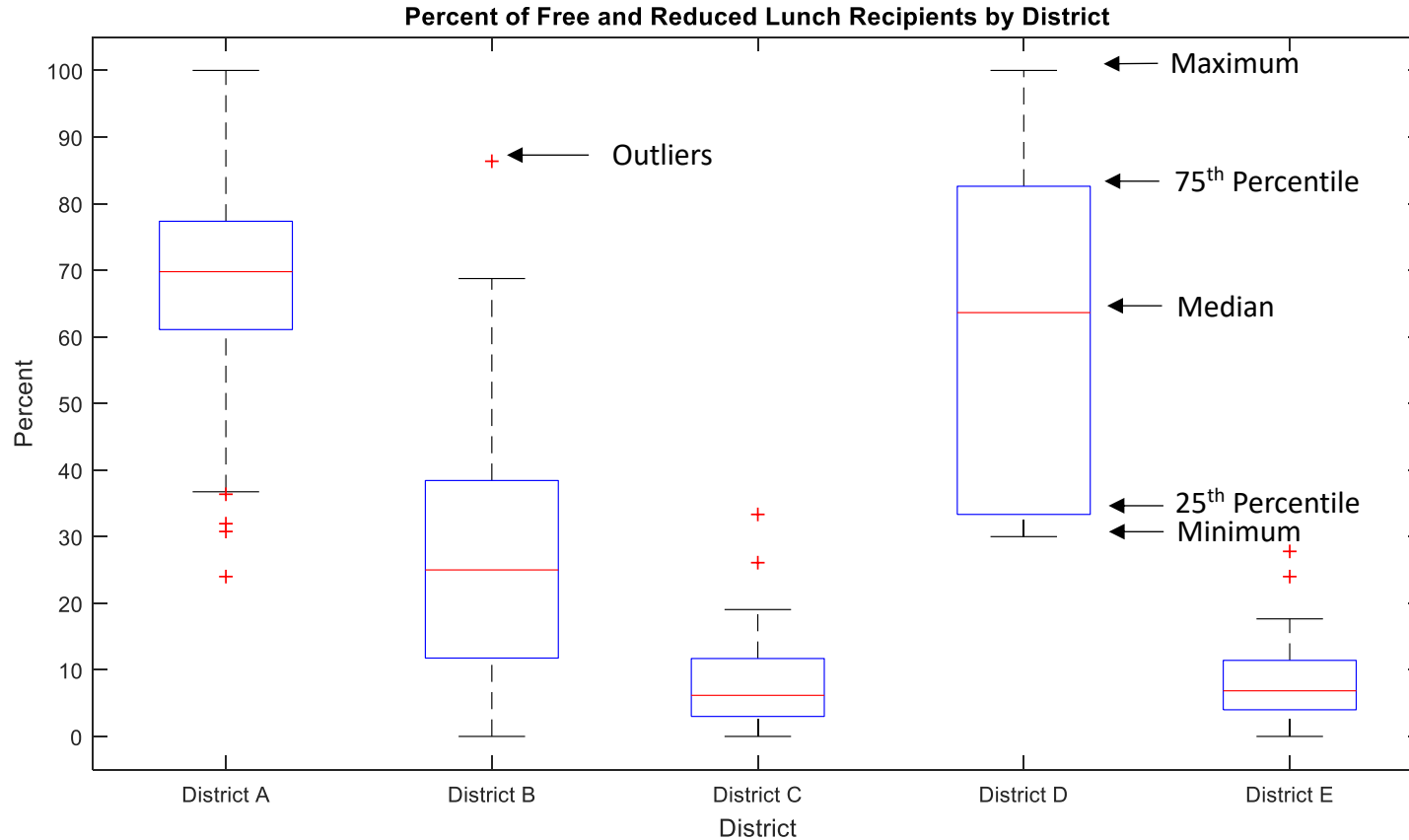
- Percent of free/reduced lunch recipients
- Percent of gifted learners
- Percent of special education

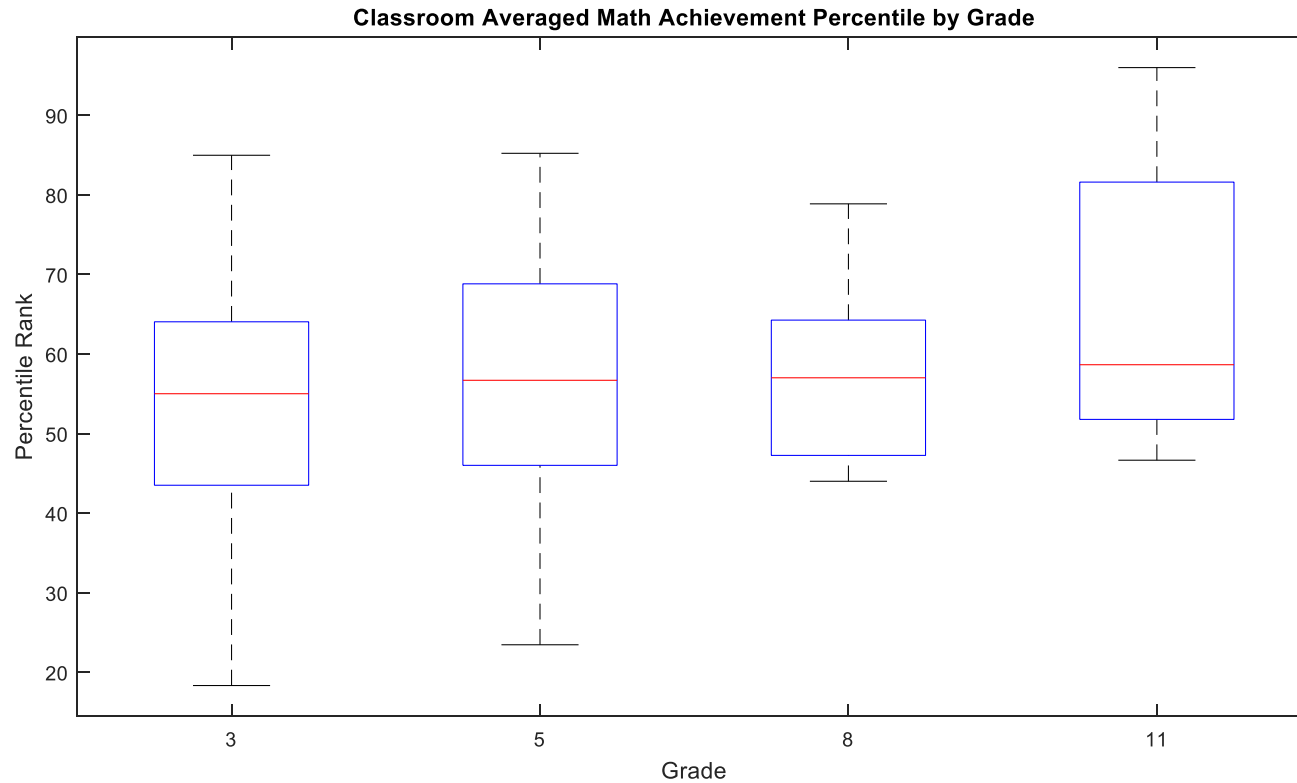
Outcome Variables (considered separately)

- Math Achievement
- Reading Achievement



Demographic Variable - %FRL





Acoustic Conditions

- Reverberation Time
- Background Noise Level
- Occupied Levels (Speech and Non-Speech)

Lighting Conditions

- Electrical Lighting
- Daylighting
- View

Thermal Conditions

- Temperature
- Humidity
- Air velocity

Indoor Air Quality (IAQ) Conditions

- Gas Phase Contaminants
- Ventilation Rates
- Particulate Matter

Gas-Phase Contaminants

- Carbon dioxide (ppm)
 - CO₂ supply, CO₂ room averaged
- Formaldehyde (ppb)
- TVOCs: Total volatile organic compounds (ppm)
 - 10.6 eV PID monitor
- Carbon monoxide (ppb)
- Ozone (ppb)

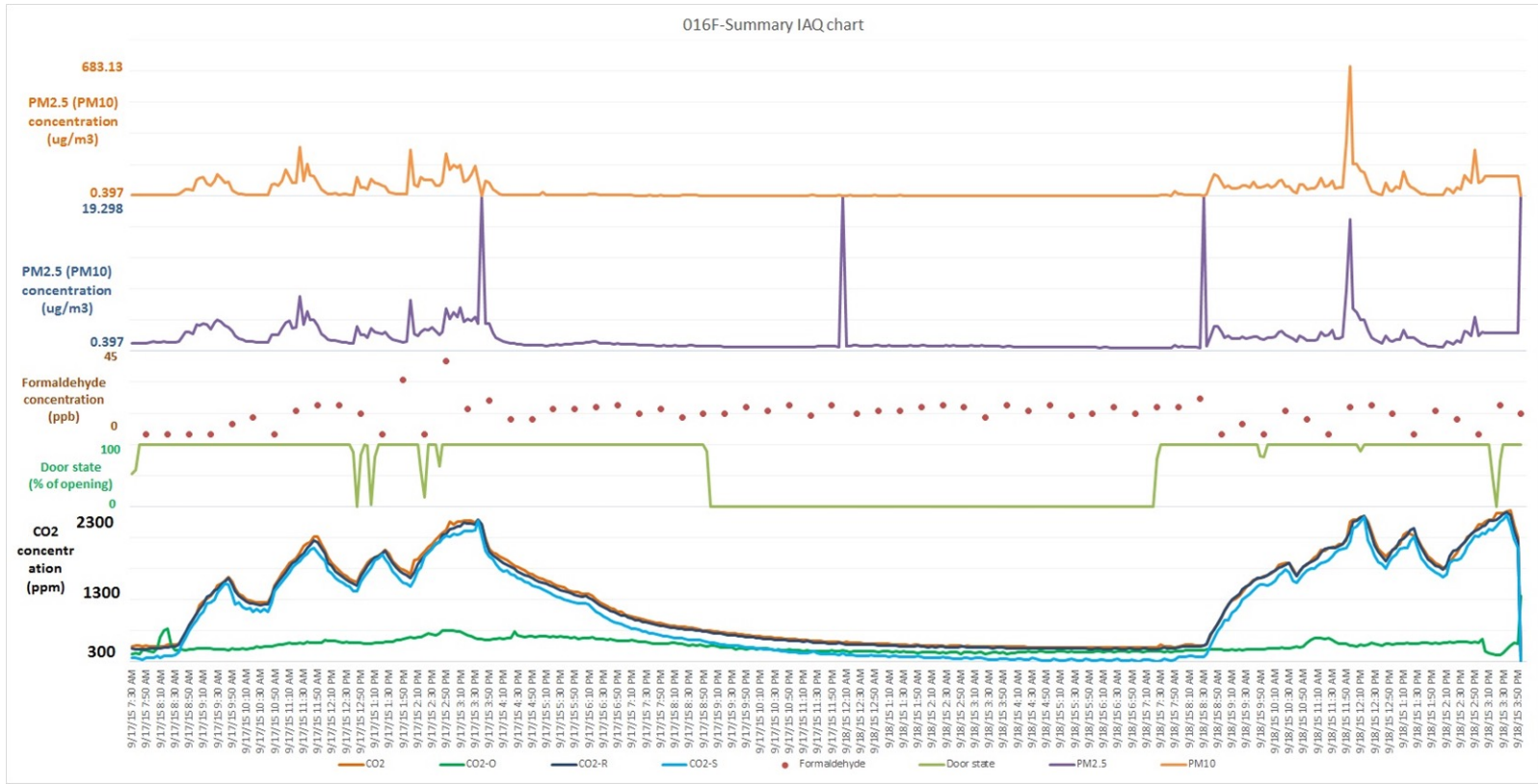
Ventilation Rates

- Estimated based on the peak concentration of CO₂ during occupied

Particulate Matter

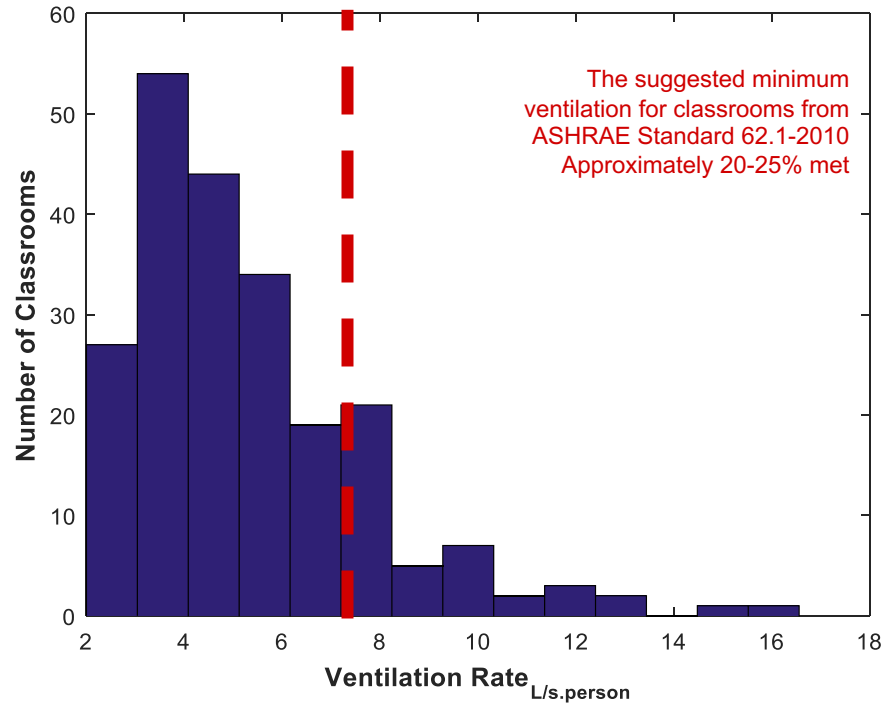
- Fine (0.3 - 2.5 micron)
- Coarse (2.5 - 10 micron)
 - From 6 channels (0.3, 0.5, 1, 2.5, 5, 10)





Example of IAQ time series data





For mathematics scores, mechanical system type, fine particle counts in fall, and CO concentration were found to be significant.

- Classrooms with unit ventilators were associated with lower mathematics scores when compared to classrooms with multi-zone systems

Outcome: mathematics scores				
Significant variables	Estimate	Standard error	p-value	Results interpretation
PFRL (percentage of free-reduced lunch students)	-0.212	0.054	<0.01	-
PGIF (percentage of gifted students)	0.388	0.155	0.012	-
Mechanical system (single-zone with unit ventilators)	-6.058	2.271	<0.01	While holding all other variables constant, mechanical system (single-zone with unit ventilators) has a lower average mathematics score than centralized with variable air volume (VAV) with recirculation pathways
Fine particles _{Fall}	0.00009	0.00003	<0.01	Higher PN25S has a positive association with mathematics achievement while holding all other variables constant
CO ^a	17.885	4.656	<0.01	^a

^a Unoccupied short-term measurement.



IAQ Findings

For reading scores, ventilation rates in fall and spring, ozone, and fine particle counts in winter were found to be significant for reading scores.

Outcome: reading scores

Significance

Seasonal variations are evident: ventilation rates in winter are significantly lower than in fall or spring for same classrooms

PGIF (p					
PFRL (p					
PSPED (percentage of special education students)	-0.525	0.102	<0.01	-	
Grade 11	-8.913	2.576	<0.01	-	
Ventilation _{Fall}	0.643	0.257	0.01		Higher Ventilation _{Fall} has a positive association with reading achievement while holding all other variables constant
Ventilation _{Spring}	-1.443	0.410	-		^b
CO	10.263	4.371	0.01		^a
NO ₂	88.428	39.956	-		^{a & b}
Ozone ^a	0.513	0.150	<0.01		^a
Ventilation _{Spring} × PGIF	0.072	0.022	<0.01		As PGIF increases, higher Ventilation _{Spring} has a greater positive association with reading achievement while holding all other variables constant.
NO ₂ × PGIF	-5.610	1.855	<0.01		^a

^a Unoccupied short-term measurement.

^b See interaction effect.



- Current study shows primarily *correlations*, not causations
 - Future studies should work with school districts to test changes or manipulations
- Meta-analysis of data gathered from 7 EPA Healthy Schools STAR projects?
- Consider studying individual student data in the future; this study covered 220 classrooms in which more than 7000 students learned



“The Efficacy of Air Filters in Classrooms on Student Academic and Learning Outcomes”

- Dr. Josephine Lau (PI), Dr. James Bovaird (co-PI)
- Funded through **Nebraska Legislative Bill 630**, partnered with Nebraska Department of Education
- September 2021 through September 2023

Methodology

- Collecting data from at least 300 third- through eighth-grade classrooms
- Each classroom randomly assigned into treatment and control conditions over two consecutive school years in 2021-22 and 2022-23



Research Questions

- 1) After controlling for student demographics, grade, school district, rurality, etc., do students in classrooms with air filters achieve **higher** academic and learning outcomes than students in the control condition?
- 2) Is there a **difference between the indoor air contaminant levels** in the classrooms with and without the installed air filter?
- 3) Does the **variation in ventilation rates** in participating classrooms relate to students' academic and learning outcomes?





Thank you!

<http://engineering.unl.edu/healthyschools/>

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Deng, S., Lau, J., 2019, Seasonal variations of indoor air quality and thermal conditions and their correlations in 220 classrooms in the Midwestern United States, Building and Environment, Volume 157, Pages 79-88, <https://doi.org/10.1016/j.buildenv.2019.04.038>

Kabirikopaei, A., Lau, J., Nord, J., Bovaird, J., 2021, Identifying the K-12 classrooms' indoor air quality factors that affect student academic performance, Science of The Total Environment, Volume 786, 147498, <https://doi.org/10.1016/j.scitotenv.2021.147498>

