Teacher knows best?

Balancing energy savings, air quality, and comfort in California's schools

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California schools have a problem

- Many California classrooms are under-ventilated
- Poor ventilation, or higher CO2 concentrations, is associated with:
  - Reduced student performance (Bako Biro et al. 2012; Haverinen-Shaughness & Shaughnessy 2015; Petersen et al. 2015; Wargocki et al. 2007)
  - Increased student absence (Mendell et al., 2013)
- Insufficient ventilation may raise exposure to formaldehyde, the largest estimated cancer risk in schools (Chan et al., 2015)
- Increasing ventilation can drive up energy consumption

Policymakers are taking steps to address it

- California Prop 39 allocated $550 million annually to improve energy efficiency in schools, K-12 and Community Colleges
- California Energy Commission Grant # EPC-15-033 is funding UC Davis and Lawrence Berkeley National Laboratory to study classroom conditions and field test advanced methods for delivering highly efficient HVAC

UCDAVIS
UNIVERSITY OF CALIFORNIA
WCEC
WESTERN COOLING EFFICIENCY CENTER

BERKELEY LAB
Lawrence Berkeley National Laboratory

STATE OF CALIFORNIA
ENERGY COMMISSION

11 schools around California participated

ID	District Enrollment	Free/ Reduced Lunch (%)[2]	Population Density (people per sq mile)	Climate Zone	Utility
1	29,917	22.6%	4,168	10	SCE
2	40,984	77.9%	5,527	12	PGE
3	54,505	86.1%	12,339	8	SCE
4					
5	1,424	62.4%	2,122	11	PGE
6	11,489	71.0%	4,368	12	PGE
7	8,582	20.3%	6,385	12	PGE
8	4,230	6.1%	5,982	3	PGE
9	6,387	18.1%	6,396	6	SCE
10	11,739	66.2%	8,454	3	PGE
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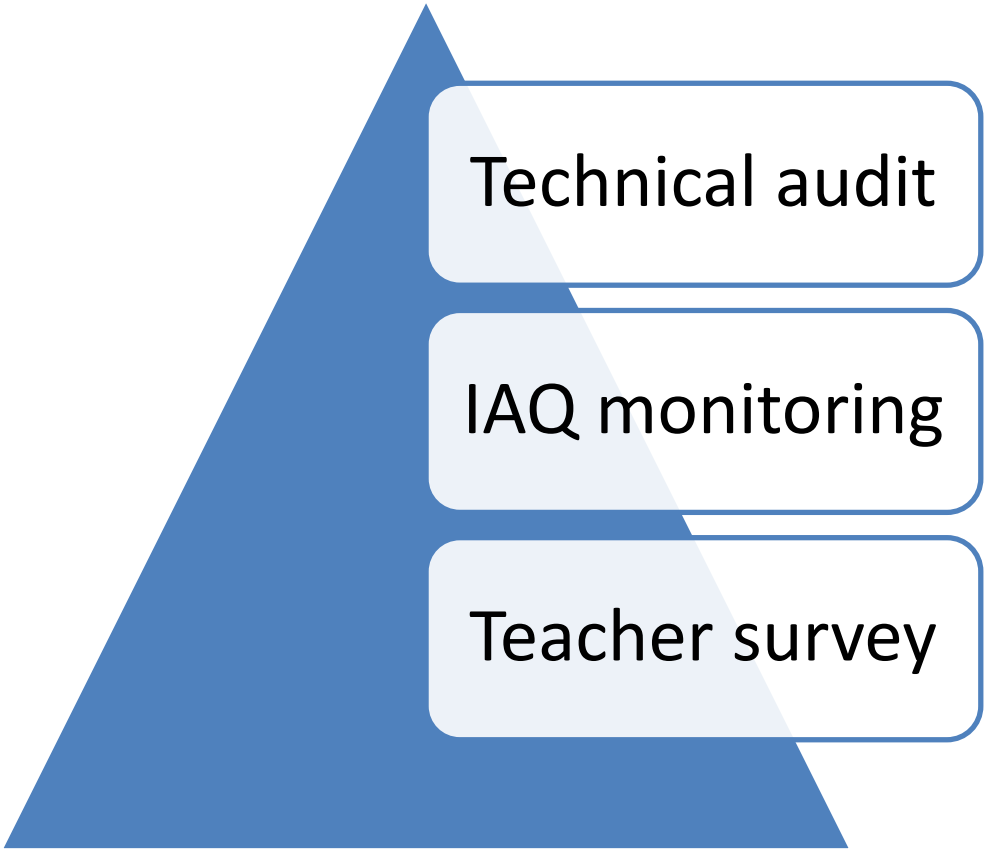
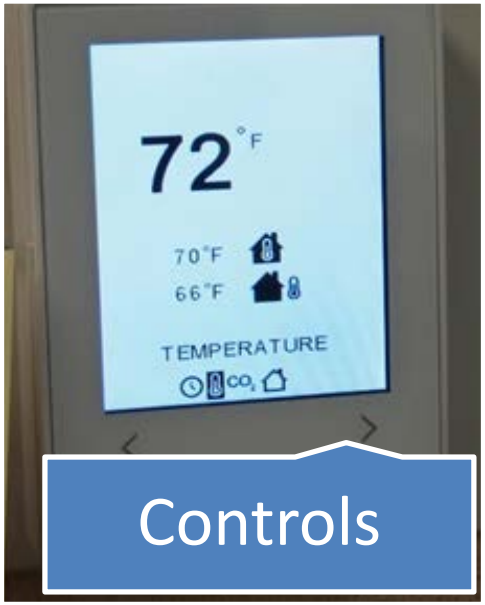
Classrooms features varied

Three data collection methods were used



3 types of problems were identified



- 51% classrooms had at least one risk factor
- 50% classrooms maintained temps within ASHRAE comfort zone at least 85% of the occupied time

Indoor Air Quality Monitoring

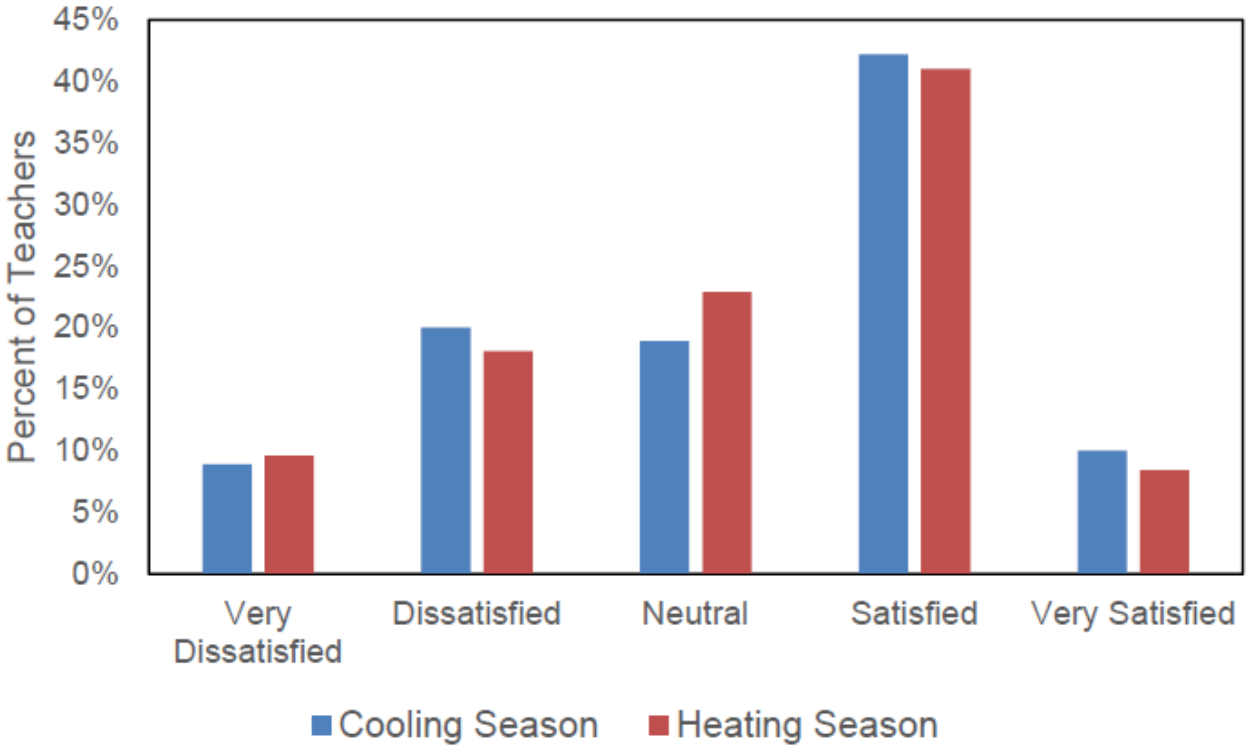
- Installed IAQ monitors for 4 weeks
- Measured CO2 concentrations, room temperature and relative humidity
- Nearly 70% exceeded 1100 ppm CO2, suggesting inadequate ventilation

Teachers were surveyed about classroom conditions

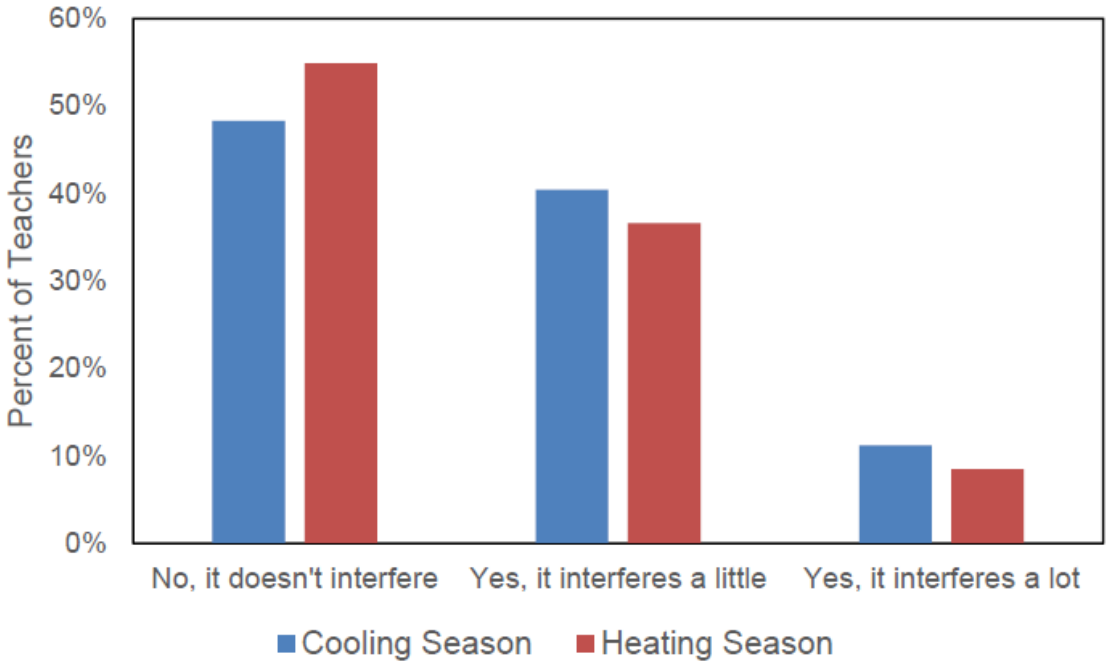
- Classroom monitoring was involuntary, but survey participation was voluntary
- 15-minute online survey, $25 Target card
- 86 teachers out of 111 invited (77% response rate)
  - 74% female
  - Most between 30-39 years old
- All grades K-12 represented
- Median class size: 27 students (ranged from 1-35)
- Occupied hours/day: mode: 8 hours, range: 4 to “more than 10”

Satisfaction with room temperatures varied

- ~50% were satisfied
- <30% were dissatisfied
- 18% were dissatisfied year-round
- >50% were either too hot, too cold, or both, at least several times a week in heating or cooling season



Classroom temperatures interfere with the learning environment

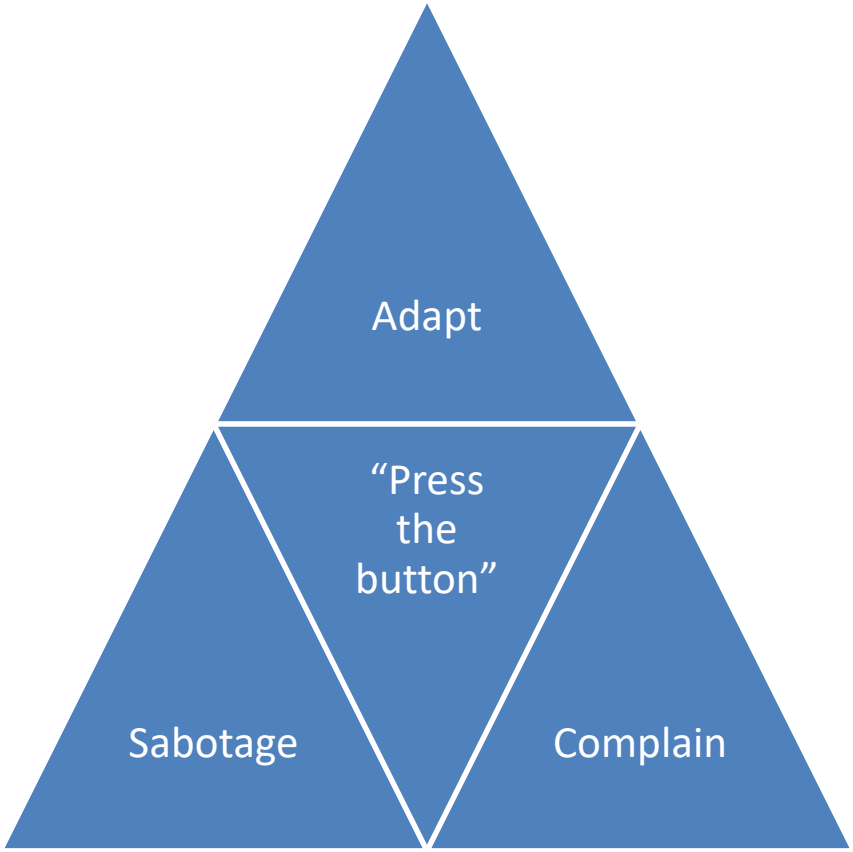


- ~50% reported interference with the learning environment
- 41% said it interfered year-round

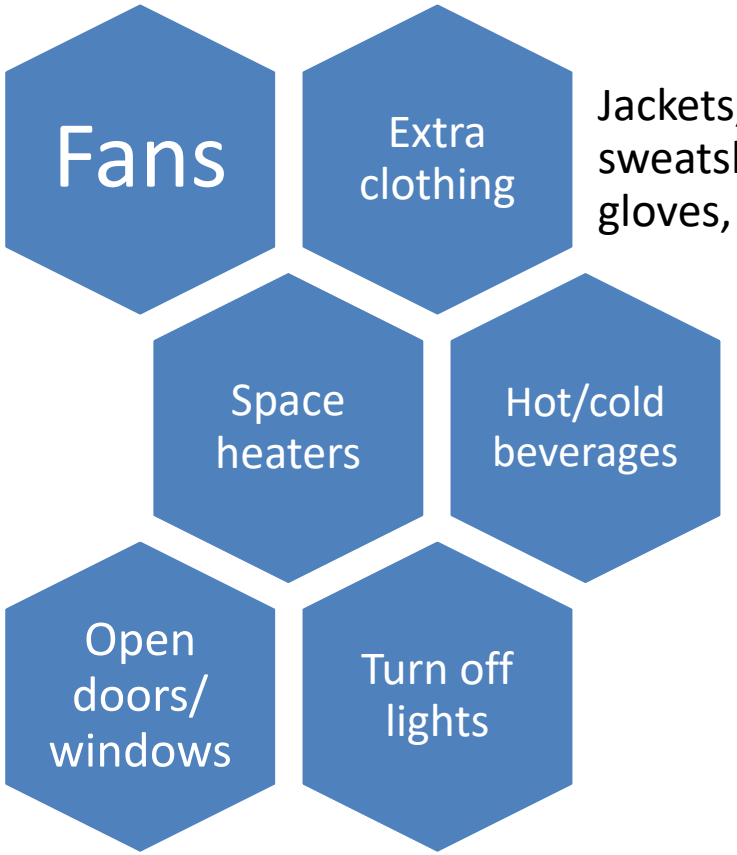
Teachers reported poor temperature control

Temperature swings	• *It's either too cold or too hot. There is not a pleasant in between setting. If I turn on the AC, it gets COLD, and when I turn on the heat, it gets HOT.*
Poor air "mixing"	• *The HVAC vents blow the air to the front of the room only. The students in the front are distracted by the cold air. while the students in the back are distracted by the heat of the room.*

Teachers respond to discomfort in various ways

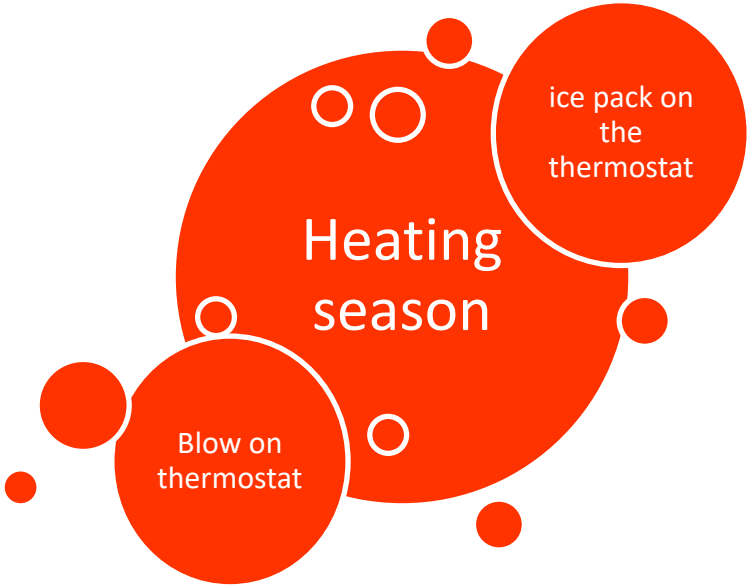


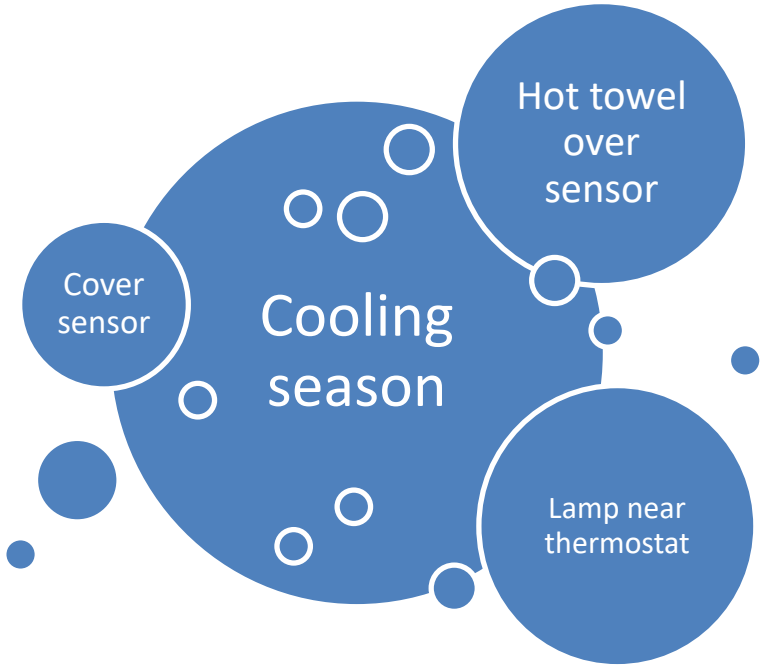
Teachers and students take pains to adapt



Jackets, scarves, sweatshirts, gloves, blankets

Some attempt to “trick” the system





Some coping strategies are very disruptive

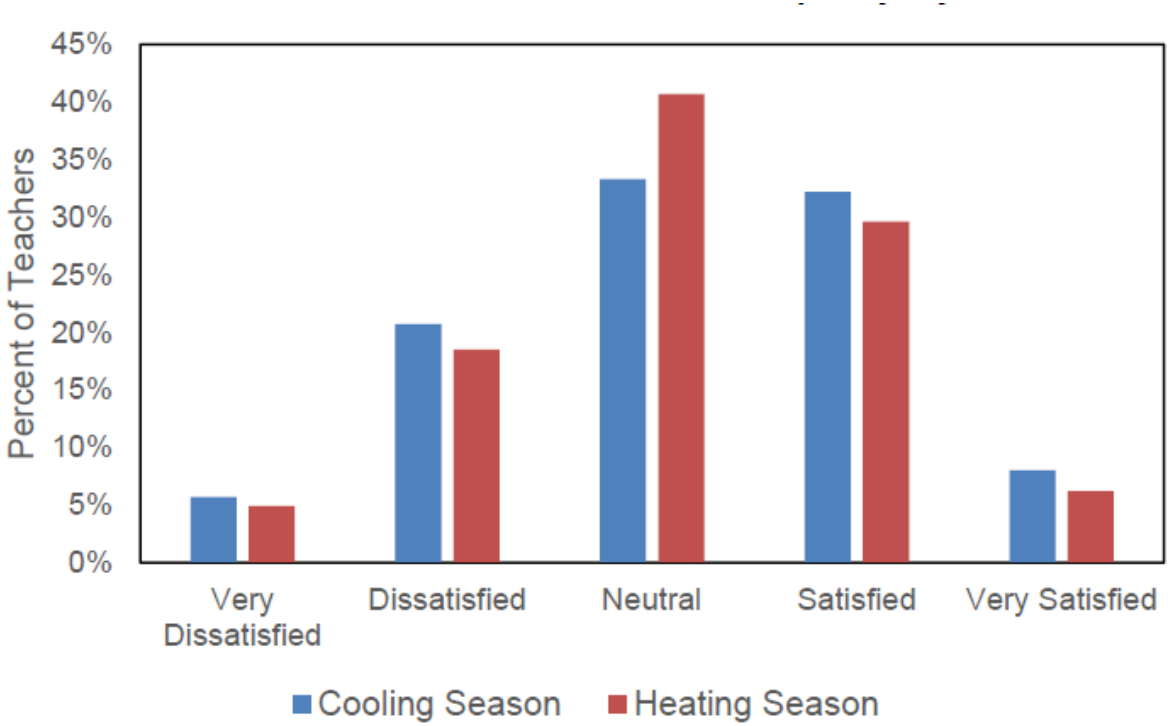
The constant interruption of turning it on and off, adjusting the temperature, and student complaints distracts from the job at hand.

I must adjust the settings every hour or so, which interrupts lessons and teacher/student interactions.

The kids are constantly putting on and taking off their jackets. It is very distracting.

Some teachers file complaints

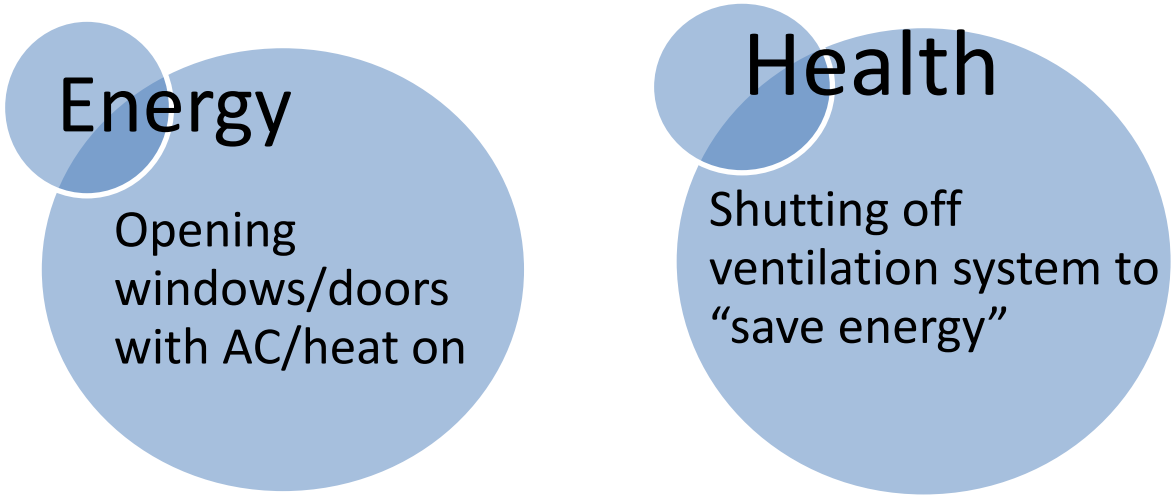
Air quality assessments were conflicting



- Neutral > Satisfied > Dissatisfied
- 1/3 said IAQ interferes with learning environment
- 59% said classroom did not get enough fresh air ("stuffiness")
- Health impacts: e.g., headaches, allergies, sinus infections, dizziness

Q: *I have never been under the impression there is "fresh" air coming into my room unless I have the door open.*

Teachers use facilities in sub-optimal ways



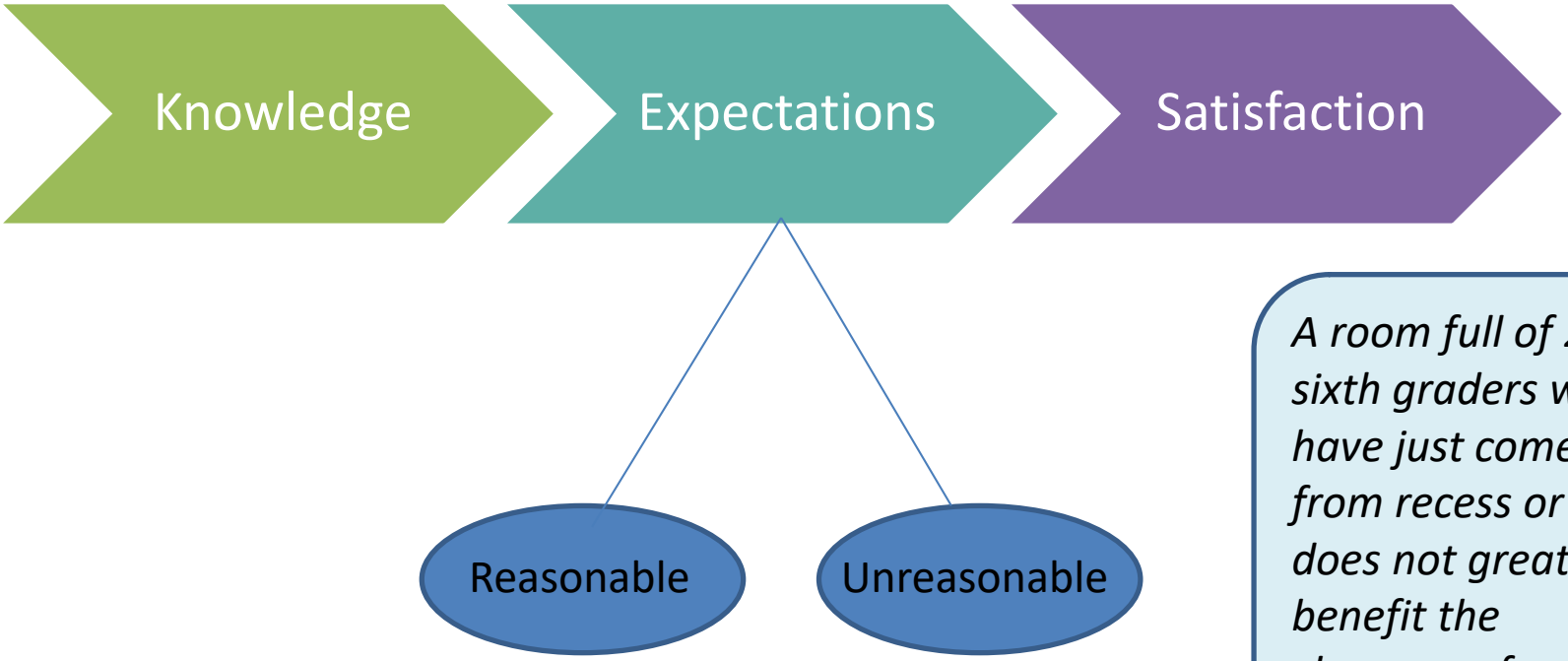
Q: *The air quality in the room is so bad that windows must be kept open at all times. With windows closed and AC/heat on,* ***it is near impossible to breathe, much less talk.*** *The air is heavy, burns lungs/throat when projecting voice, and smells bad (moldy/dank/old/dusty).* ***Due to low air quality, windows always have to be open.***

Teachers' IAQ assessment didn't correlate with monitoring results

	Satisfied	Not satisfied
Adequate ventilation	15	3
Inadequate ventilation	12	15

Cell values indicate number of teachers. N=45, excluding "neutral" reports

Differences in expectations *may* account for surprising findings



A room full of 29 sixth graders who have just come in from recess or PE does not greatly benefit the classroom freshness quotient.

Conclusions & Recommendations

- Poor IAQ is prevalent and problematic for California students
- HVAC equipment problems need to be addressed
  - Adopt system to verify proper installation
  - Ensure filters are changed on a reasonable schedule
  - Install CO2 sensors as a control or alarm mechanism
  - Take teacher complaints about IAQ seriously
- Occupants need to understand how thermostats work and what they do
  - Train occupant on correct operations/functions, and explain the why and how
  - Satisfaction is not a reliable diagnostic tool. Train occupants on what problems to report.

Questions?

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Look for our report to the CEC in early 2018.