Report on Ventilation Testing of Kennedy-Longfellow and Cambridgeport Schools

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Executive Summary:

A ventilation assessment was completed in 2 classrooms at the Kennedy-Longfellow School and 2 classrooms at the Cambridgeport Schools. Based on standards set by Joseph Allen (Harvard Chan School of Public Health) and Shelly Miller (University of Colorado, Boulder), Cambridge Public Schools will require occupied classrooms to have a **minimum effective 4.0 ACH** (air changes per hour) and have a goal to keep every classroom above 5.0 ACH whenever possible.

The Cambridgeport and Kennedy-Longfellow Schools have baseline ventilation between 1.3-2.0 ACH from existing mechanical ventilation and have been identified by teachers and families as having poor ventilation. Ventilation rates were measured using existing mechanical ventilation alone and in combination with variations of 2 open windows (4 inches), box fans in various configurations and open doors (to a hallway). Maximum ventilation was achieved when windows were open 4 inches, each window had a box fan blowing in opposite directions and a door was open to the hallway. That configuration provided **over 4 ACH** in each classroom tested.

Though ventilation from windows and box fans will vary based on window placement in the room and prevailing wind outdoors, opening 2 windows in every classroom and having a 2 box fans blowing in opposite directions should consistently provide over 5.0 ACH.

Cambridge Public Schools has purchased HEPA filters (air scrubbers) that provide 450-500 cfm of filtered air. Those will add an additional 2.3-3.4 effective ACH to each classroom.

Best practices for classroom setup:
Fresh air adds additional safety to spaces and should be maximized where possible. To improve ventilation further at the level of individual rooms, the following procedures should be followed in setting up classrooms:

- Open every operable window 4 inches (code-maximum) unless weather/conditions outside make open windows unsafe. If the classroom gets too cold, only open 2 windows (if more are operable).
- Open hallway doors if it is safe to do so. If the classroom has a door to the outdoors (i.e. a fenced in playground), keep the door open if it is safe to do so.
- Depending on how many windows you have, put a box fan in 1-2 open windows. If the windows are far apart, set one fan blowing in and one blowing out. If there is only one window, or two open windows are close to each other, place both fans blowing inward as long as it is not blowing directly across people. If fans would blow across people, then point them outward.
- In schools that don't get 4+ equivalent clean air exchanges per hour from central ventilation systems and are unable to open 2 windows, portable HEPA filters/air scrubbers should be placed in a central location in the room. This will achieve equivalent air exchanges and add filtration to the room. Make sure any cords are taped down so students don't trip. Avoid HEPA filters blowing directly across students.
- If you are using portable HEPA filters/air scrubbers, set the unit to the highest setting if windows are closed (i.e. too cold, bad weather). If the windows are open then set the air scrubbers to the lowest setting or leave off.
- Whenever possible, keep the door to the hallway or an enclosed outdoor area open unless student safety is an issue.

Procedures for Determining Outdoor Air Ventilation Rate using the CO_2 Decay Method

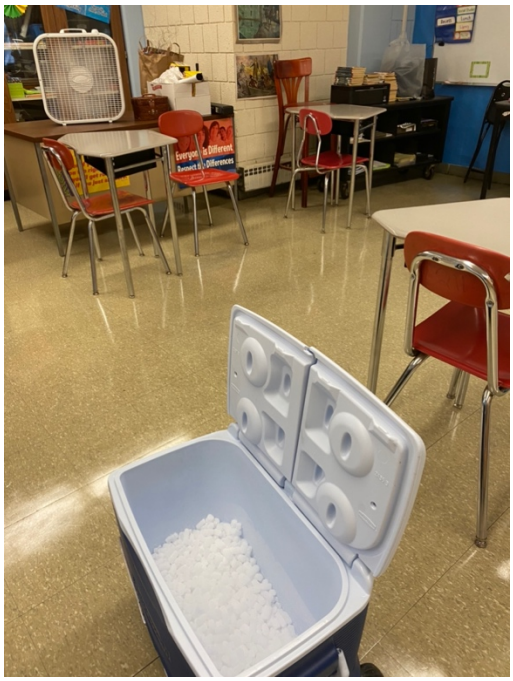
1. Classrooms randomly chosen for testing. In each school 1 classroom with windows on a single wall and 1 corner classroom with operable windows on 2 different walls were tested.
2. Classroom windows and doors closed. School mechanical ventilation turned off. Anyone in building advised to be alone in a room and open windows while existing mechanical ventilation was turned off.
3. Outdoor CO_2 measured and logged
4. Dry ice (frozen CO_2) used to raise classroom CO_2 above 1500ppm using box fans in the classroom to distribute the CO_2.
5. Dry ice removed from classroom in a closed cooler.
6. Building ventilation turned on. Once building ventilation verified on, CO_2 logged every 5 minutes for 15 minutes. CO_2 was measured at least 6 feet from the dry ice cooler.
7. 2 windows opened 4 inches each. CO_2 logged every 5 minutes for 10-15 minutes.

   (The following procedures were completed in 2 of the 4 classrooms.)
8. 2 box fans placed in window blowing out. Door opened. CO_2 logged every 5 minutes for 10 minutes.
9. 2 box fans placed in windows blowing in opposite directions (1 in, 1 out). Door remained opened. CO_2 logged every 5 minutes for 10 minutes.
10. Outdoor CO_2 measured and logged.
11. The following equation was used to calculate a total ACH from fresh air for each condition.

$$ACH = \frac{-1 * ln\left(\frac{C_{end} - C_{ambient}}{C_{start} - C_{ambient}}\right)}{t_{end} - t_{start}}$$

Notes:

1. During recording 1-2 people stayed in the room to record. The CO_2 in exhaled breath of those individuals could cause a small underestimate of the room ventilation.
2. Procedure adapted from Joseph Allen, Jack Spengler, Emily Jones, Jose Cedeno-Laurent; Harvard Healthy Buildings program; **5-step guide to checking ventilation rates in classrooms;** August 2020, option C

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Results

School/classroom	Fresh Air from Mechanical Ventilation (From engineering report)	Fresh Air from Mechanical Ventilation (measured)	Fresh Air from ventilation + 2 Windows (open 4 inches)	Fresh Air from box fans blowing out (low)/open door to hallway +windows +ventilation	Fresh Air from box fans (one blowing in/one blowing out) +windows + doors +ventilation
Kennedy-Longfellow 202 (hallway room)	1.7	1.4	3.6	Not tested	Not tested
Kennedy-Longfellow 209 (corner room)	1.7	2.3	3.5	Not tested	Not tested
Cambridgeport 207 (hallway room)	1.5	1.1	2.35	3.5	4.1
Cambridgeport (corner room, one ventilation unit in closet)	1.5	1.5	3.1	4.5	8.5

Box fans blowing in opposite directions with 2 windows open 4 inches each and a door to a hallway open achieved an ACH > 4.

Room to Room Variation

These randomly chosen classrooms suggest that there is room to room variation in ventilation from mechanical ventilation within a school. The planned balancing of ventilation systems is important to ensure consistent ventilation from mechanical ventilation in the winter when temperatures may be too low to keep windows open and fans on.

Using CO2 meter to measure ongoing ventilation of occupied spaces

Ventilation from fresh air and windows can be checked by using CO_2 meter in a classroom after students and teachers have been present for several hours. If all of the ventilation is from **outdoor air** then the CO_2 level in a classroom should not exceed 800 ppm at 4.0 ACH. Measure the CO_2 concentration with the CO_2 sensor for at least five minutes. While the background concentration outdoors is approximately 400 ppm, in denser urban areas, CO_2 can fluctuate throughout the course of the day due to emissions from combustion sources. Take note of the

outdoor concentration as that can influence the steady state CO_2 in a classroom. MERV13 filters and portable HEPA filters provide additional effective ACH for protection against viruses including COVID-19 but do not reduce CO_2. In a classroom with closed windows depending on an in-room HEPA filter or central MERV13 filter to provide clean air, CO_2 could be higher than 800 ppm. How high CO_2 could be will depend on the percent of recirculated air, the size of the classroom and the number of students and teachers. As a rule of thumb, ventilation should be reevaluated using the specifics of the room if CO_2 is over 1000ppm for over 5 minutes. CO_2 should be measured near the center of a classroom but over 6 feet from people.

Layers of Protection

Ventilation is most important to protect against viral spread beyond 3-6 feet and in situations when masks must be removed including during meals. Ventilation should be used in conjunction with other layers of protection including physical distancing, masks or face-coverings, hand-washing, disinfection of high touch surfaces and testing and symptom screens.

Ventilation with fresh air provides extra protection when another layer of protection may be relaxed, such as while eating in a classroom. Even in cold weather, windows should be open with fans blowing out (to minimize classroom breezes) while students, faculty or staff are taking a mask break in shared spaces unless other conditions outside make it unsafe to open windows briefly.

Appendix 1: Raw Data and Calculated ACH in tested classrooms

KLo 202	8:30 AM		464
hall classroom	10:00	(ventilation not full strength)	2157
	10:05	ventilation + windows open	1974
	10:10		1620
	10:15		1324
	10:20		1083
	10:25		915
Klo 209	10:52	(ventilation turned on)	1894
corner room	10:57		1664
	11:02	windows opened	1436
	11:07		1185
	11:12		1020
	11:17		875
	11:25	outside	441
Cport 207	9:30	outside	428
	9:32	room baseline	577
	9:43	ventilation on	1574
	9:48		1504
	9:53		1377
	9:54	open windows	
	9:59		1199
	10:05	box fans blow out low/door open	1026
	10:11		873
	10:17		730
	10:19	open windows/doors/box fan 1 in/1out	702
	10:23		640
Cport 304	10:35	outside	441
(corner windows, one ventilation unit in closet)	10:35	room baseline	493
	10:49	ventilation on	2054
	10:54		1942
	10:59		1705

11:02	open windows	1577
11:09		1242
11:12	2 box fans blow out/door open	1122
11:17		901
11:22	open windows/doors/box fan 1 in/1out	763
11:27		600