Summer 2019

PSU Green Building Internship Final Report, 2019: Karl Miller Center Post-Occupancy Study

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PSU Capital Projects and Construction - Green Building Internship

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Executive Summary

This study examined the effectiveness of the passive cooling strategies in the Karl Miller Center (KMC) at Portland State University. Due to the warm temperatures reached in Portland during the summer months and the absence of a mechanical cooling system on the Pavilion side of the KMC, classrooms can exceed thermal comfort preferences on a number of occasions. Previous studies have recommended taking certain classrooms “offline” after 12pm in the summer, where they are only available for morning classes. This study aimed to update the classroom prioritization as well as analyze the employed cooling strategies and begin a long term air quality study. A survey was distributed to students taking summer classes in the KMC Pavilion with questions regarding their thermal comfort, air quality perceptions, and knowledge of the in-room window and ceiling fan controls. The responses were analyzed in conjunction with indoor and outdoor temperature data and input from stakeholders around the PSU campus.

We have concluded the building is operating as designed, even if that means comfort levels were exceeded. Based on a weighted average of overheating days, rooms 295 and 495 were deemed the most suitable for holding classes, rarely exceeding 80℉ in summer 2019. Students were overall comfortable on average up to an indoor temperature 77℉ without the ceiling fans turned on. We also continue to recommend the classrooms most prone to overheating be taken offline after 12pm during the summer term.

The most significant opportunities for improvement are user education and night flush techniques. Most students surveyed either had not used, or did not even know of the in-room wall controls that are essential to maintaining comfort levels in a naturally ventilated environment. The Campus Planning, Facilities and Property Management, and Capital Projects and Construction offices at PSU are taking the next steps to provide increased education to the building’s occupants in the form of posters and a possible how-to video.

Through a variety of field tests, we determined the most successful night flush procedure is to turn on the rooftop exhaust fans while the windows are open to draw in the largest volume of cool air possible during the nighttime hours. However, this may take away from the building’s sustainable design as the energy use of the exhaust fans is not negligible.

Purpose of Study

This study aims to evaluate the passive cooling design of the Karl Miller Center, a mixed-use and mixed-mode ventilated building on the Portland State University campus. The data collected during this study will be compared to the design-intent of the building in order to determine if the passive ventilation is performing as intended. Occupant surveys as well as building automation system (BAS) data will be used to update conclusions of previous studies regarding occupant comfort and knowledge of the building's features. This information will also inform future planning decisions at Portland State University.

Limitations

- Building Automation System (BAS) data regarding window operation was not consistently accurate to truly reflect the state of the windows at a given date/time.
- Only a select few classrooms in the KMC Pavilion received surveys due to a lack of interest from faculty.
- Particulate pollutant levels in the Portland-Metro area stayed consistently low during the period of this study so as to render any differences in indoor and outdoor concentrations negligible.
- The majority of classrooms in the KMC Pavilion were "offline" after 12pm, meaning they were not used for classroom scheduling, and generally unoccupied. Therefore, temperatures observed in the rooms may not be representative of the temperature during a class period, due to the absence of internal heat gain from occupants.
- Air velocity in the classrooms was not measured due to the difficulty of measurement.

Previous Studies

Study of Lattin in Fall 2017

Prior to summer 2019, the KMC was subject to two post-occupancy studies. The first of which was an undergraduate architecture honors thesis by Kythetica Lattin.[1] Conducted during the Fall of 2017, this study surveyed 23 classes across 8 Pavilion classrooms totaling 743 survey responses. The majority of courses took place in the evening. In addition, the fall term at Portland State does not begin until the last week of September. Therefore, exterior temperatures during the study period were not high enough to provide a sufficient test of the natural ventilation system of the building. 80% of students taking classes in the Pavilion reported satisfactory comfort levels. This is in accordance with the ASHRAE 55 standard, which states that a building must have at least 80% of occupants experiencing thermal satisfaction to be in accordance with the standard. To compare, 82% of students taking classes on the renovated side of the KMC reported satisfactory comfort levels. This is significant, as the renovated section of the building is mechanically cooled. One would expect a notably higher rate of satisfaction from the mechanically cooled portion of the building, only here that is not the case.

Study of Abu Salaiman and Jocelyn Reynolds in Summer 2018

Omar Abu Salaiman and Jocelyn Reynolds were the Portland State University Green Building Interns for summer 2018. At this time, in response to numerous complaints of KMC Pavilion classrooms being too warm in the summer months, there were not any classes scheduled in Pavilion classrooms for the entire summer of 2018. Abu Salaiman and Reynolds surveyed students taking classes in the renovated portion of the building, which is mechanically cooled in order to calculate a “comfort band”, i.e. a set of temperatures across which occupants answered satisfactory on average. The upper limit of this band was decided to be 75℉ for an empty classroom with the ideal temperature range existing between 68 and 73℉. As a result, classrooms 180 and 185 were chosen to be the most suitable for classes, with 295 and 285

[1] Lattin, Kythetica (2018). *An Indoor Environmental Quality Assessment: The Study of Naturally Ventilated University Classrooms within a Mixed-Mode Ventilated Building.* Portland State University.

recognized as semi-suitable and the remainder as not suitable for summer classes. Certain rooms were recommended to be “offline” in the afternoons, and not hold classes after 12pm in the summer months. In addition, the researchers collected daily temperature changes of the concrete slabs in the building in order to evaluate the night flush procedure. A successful night flush yielded a 1 to 1.5 degree overnight surface temperature decrease of the interior concrete slab.

KMC Natural Ventilation Design Intent

During the design phase of the major renovation, a study from Behnisch Architekten included a simulation of how the temperature in the interior of the KMC Pavilion would perform if constructed as intended.

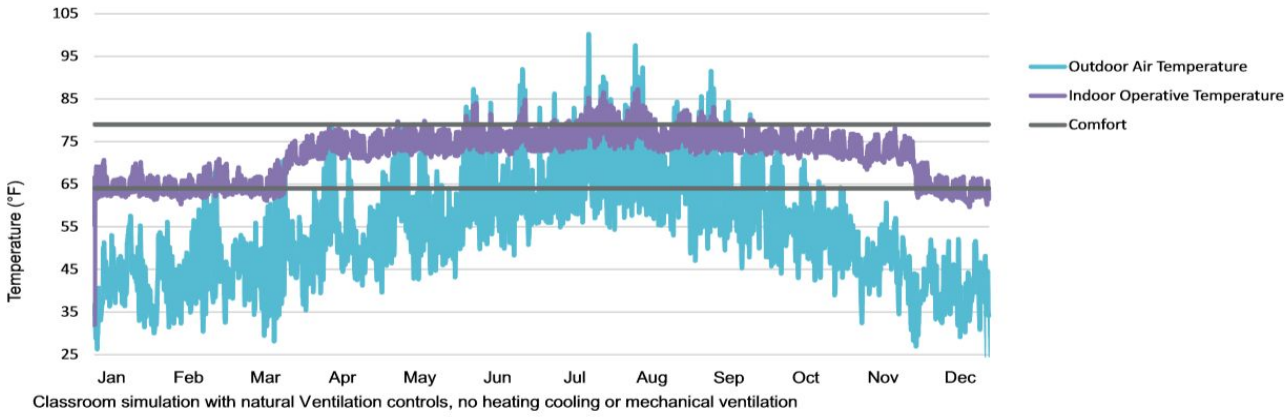

Figure 1. 2015 Behnisch Architekten Pre-Design Natural Ventilation Simulation

The comfort bands of interest, calculated by the design team, are situated at 64℉ and 78℉. It can be discerned from the figure that the KMC rooms would frequently have indoor air temperatures in excess of 80℉ throughout the summer. This was deemed to be uncomfortable, and unfortunately the design report mistakenly states that there are not any summer classes held in the Pavilion classrooms. Also in this report is an aside that shows the upper comfort limit increasing as overhead air circulation is increased. To expand on this claim, a scale was developed in which the upper comfort limit would be raised proportionally with the increased air circulation provided from local ceiling fans installed in each classroom.

Overheating Hours at Various Upper-band Comfort Limits
(Operative Temperature, Occupied Hours Only)

>78°F	>80°F	>82°F	>84°F
No Fan	Fan Air Speed 25 fpm	Fan Air Speed 55 fpm	Fan Air Speed 100 fpm

Figure 2. Fan Speed and Comfort Limits - 2015 Behnisch Architekten Pre-Design

Research Goals and Methods

Research Goals

1. Distribute and analyze surveys to students taking classes in Pavilion classrooms during summer 2019.
2. Use survey results and classroom temperature data to update scheduling priorities for Pavilion classrooms.
3. Initiate long-term particulate-focused air quality monitoring by deploying sensors in selected classrooms and outside environments so as to best discern differences between particulate concentrations in naturally and mechanically ventilated spaces.

Methods

- Coordinate with PSU Campus Sustainability Office for survey design and Internal Review Board (IRB) approval.
- Consult previous studies and seek input from project stakeholders regarding survey design.
- Contact faculty with classes in the Pavilion during summer 2019 and invite to participate in the survey.
- Distribute surveys in-class during the summer 2019 term. Each participating will be surveyed once, with the exception of one in which a second survey was distributed.
- Analyze BAS reports to identify trends in temperature between classrooms and correlate to survey responses.

- Collect data from the National Oceanic Atmospheric Administration (NOAA) and National Weather Service (NWS) databases regarding outdoor air temperature in the area.
- Construct recommendations based on data analysis and occupant responses.
- Deploy air quality monitoring instruments in select classrooms and outdoor areas and preliminarily analyze summer 2019 data.

Survey Design

The survey distributed was a two-page document fitting on a single sheet of paper (printed front and back). The first page was a consent form notifying the participant of their willing participation and purposes of the study. The reverse side contained the actual survey questions. The survey featured six multiple choice and one open-ended question. Two of the questions were related to thermal comfort with the first one asking the student how comfortable they have been over the entire duration of the summer term. The second thermal question inquired how the participant felt at the exact moment they received the survey. Other questions addressed the wall-mounted fan/window controls, perceived air quality, and whether or not they were informed of the sustainable features of the KMC. The last question was left for written comments. All responses would be logged into a spreadsheet, comments included, and numerically coded for ease of analysis. The survey was distributed at a time during the class period, as decided by the instructor. The researchers also gave brief introductory remarks about the scope of the project upon delivering the survey.

Quantitative Data Collection

Siemens Insight Reports (Building automation system)
Metrics: Room-specific air temperature and CO2.
Intervals: 30 minutes.

Kestrel Drop D2 Data Logger
Metrics: Air temperature, relative humidity, dew point, heat stress index.
Intervals: 5 minutes.

www.kestrelmeters.com

Purple Air Particulate Concentration Sensor
Metrics: PM 0.5,1.0,2.5,10
Intervals: 80 seconds.

www.purpleair.com

HOBO Onset Weather Station
Metrics: Wind speed, wind direction, temperature, relative humidity
Intervals: Adjustable

Raw Data/Results

Summer 2019 Indoor/Outdoor Temperature Summary

Compared to summer 2018, the summer 2019 season has been significantly cooler. The average overall temperature for the period 6/1/2018 to 8/24/2018 was 69.3℉ while the average for the same period in 2019 was 67.6℉. The 1.7 degrees difference in average temperature will

need to be taken into consideration when making future planning decisions as it is unlikely this will be the state of future summers as the overall average temperature has risen in recent years.

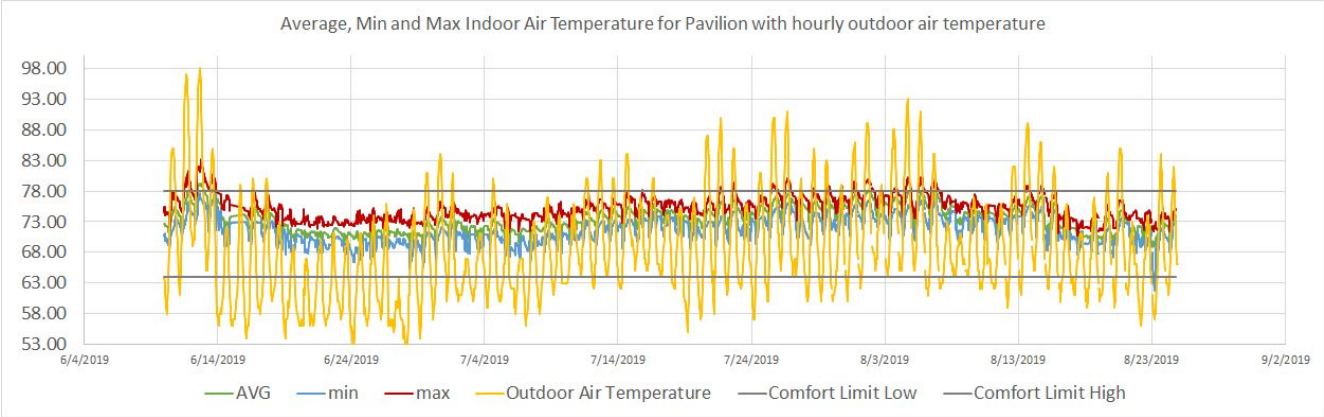

Figure 3. Summer 2019 KMC Indoor Pavilion Classroom Air Temperatures and NWS Outdoor Dry Bulb Temperature

In the above figure, the comfort bands at 64 and 78℉ have been transferred from the pre-design study. For only 16 days during the summer of 2019 did at least one classroom exist that exceeded the upper band of 79℉. This was often classroom 390, but in rare cases included other rooms as well.

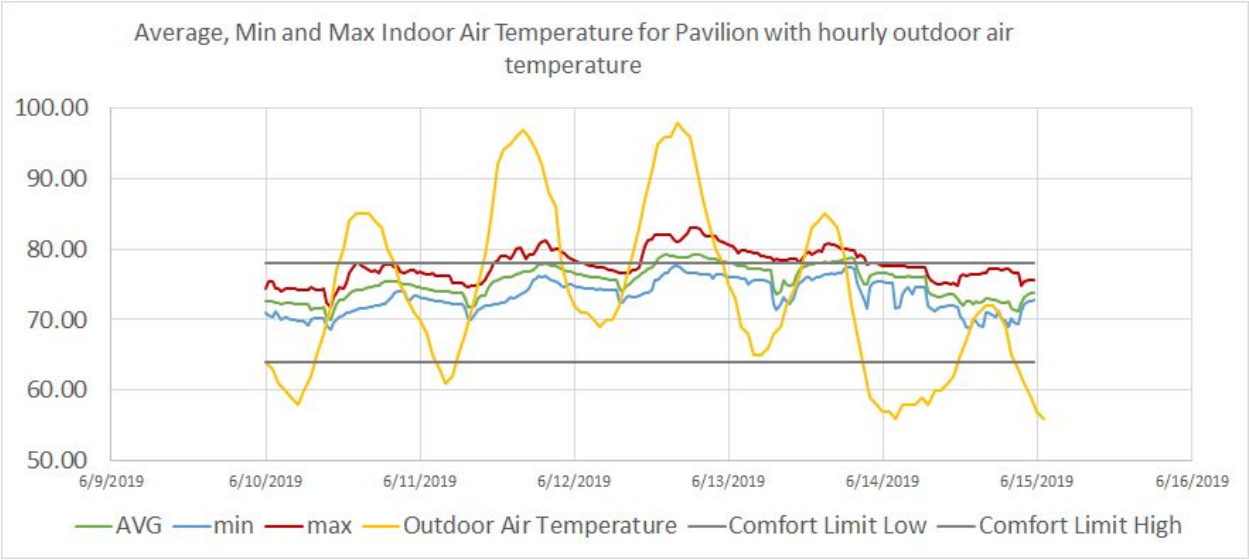

Figure 4. Summer 2019 KMC Indoor Pavilion and Outdoor Dry Bulb Temperatures: 6/10/2019-6/15/2019

The most notable time period was June 10th-14th, coinciding with final exams for spring term 2019. The high temperature for a Pavilion classroom during this time frequently exceeded the comfort band. These high outdoor air temperatures are often typical in a Portland summer

although they were not often experienced during summer 2019. A night purge analysis was also conducted during this time.

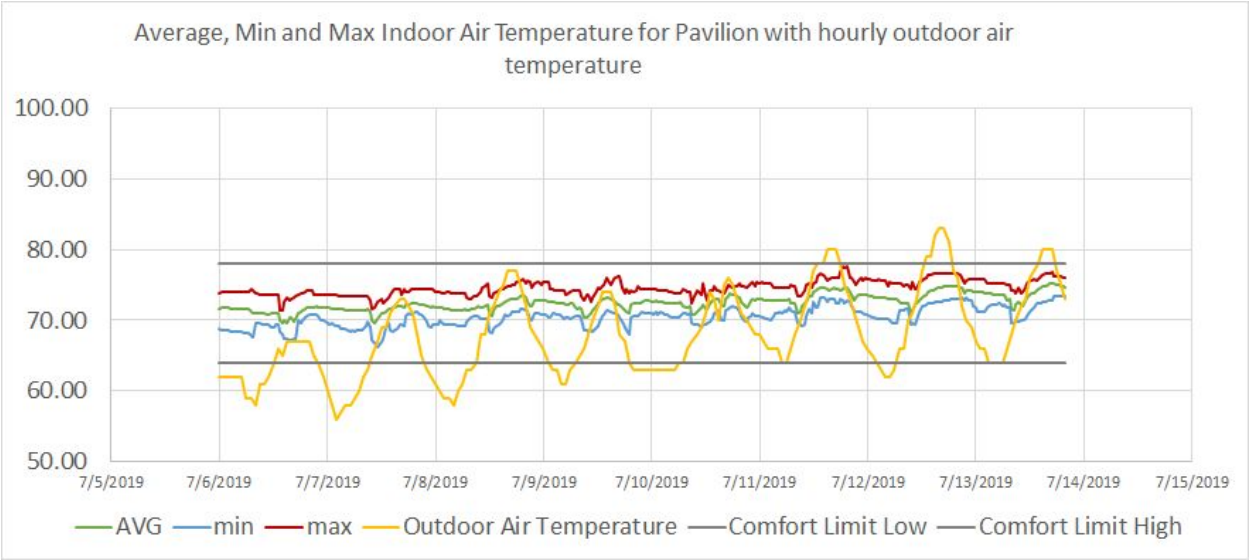

Figure 5. Summer 2019 KMC Indoor Pavilion and Outdoor Dry Bulb Temperatures: 7/6//2019-7/14//2019

The week of 7/6/2019 to 7/14/2019 represents a variety of temperature ranges that were often replicated during the research period. At these outdoor temperatures, the indoor temperature of Pavilion classrooms stays within the prescribed comfort bands. Only when outdoor temperatures exceed 88℉ do the Pavilion classrooms begin to drift out of the ideal comfort zone.

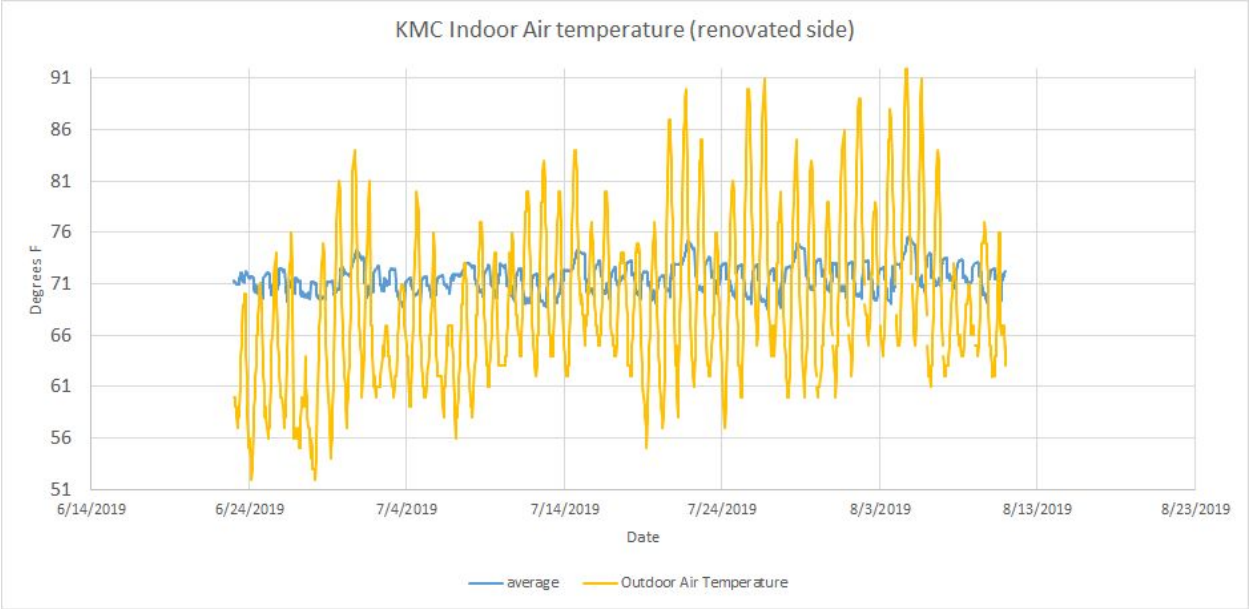

Figure 6. Summer 2019 KMC Renovated Classrooms Average Air Temperature and NWS Outdoor Dry Bulb Temperature

To compare, the average temperature on the renovated portion of the KMC consistently stays within the set points, as it is mechanically cooled.

Survey Results

Table 1. Survey Distribution Summary

Survey No.	Classroom	Participants	Date and Time of Distribution	Indoor Air Temperature	Outdoor Air Temperature
1	185	23	7/23/2019 5:30 PM	74	74
2	185	16	7/24/2019 5:30 PM	75	80
3	295	19	7/25/2019 10:30 AM	73	76
4	185	14	7/25/2019 12:45 PM	75	84
5	190	21	8/1/2019 10:30 AM	77	77
6*	295	30	8/15/2016 10:30 AM	77	71

**Repeat of survey 3 class with increased attendance*

The first set of survey distributions were completed during the last week of July and first week of August. At this time, the outdoor air temperature was in-line with the current summer averages, but below the 2018 averages. The sixth and final distribution occurred during the third week of August. Unfortunately the ending of summer term classes and final exams provided a significant

hurdle to conducting repeat surveys in four of the five classes. However, the total number of responses, at 104 will still serve as a reliable representation of students.

Overall Comfort

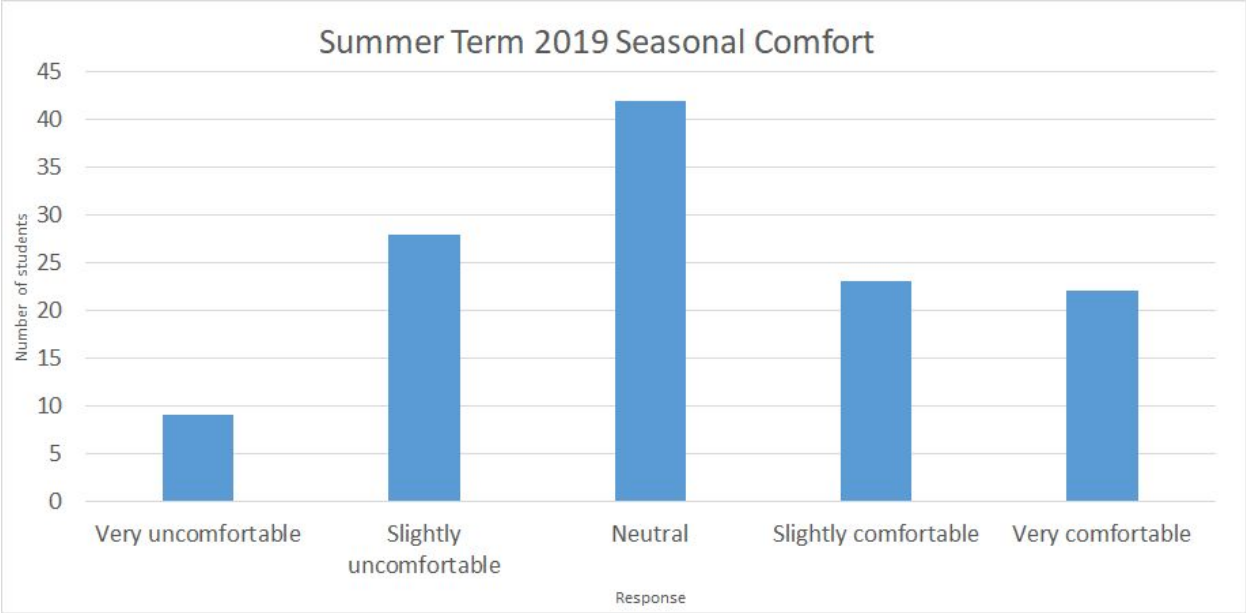

Figure 7. Summer 2019 Cumulative Comfort Levels in KMC Pavilion Classrooms

On average, students are satisfied with their seasonal comfort in KMC Pavilion classrooms. Only 9 out of 115 responses were registered as “very uncomfortable” while the remaining 106 lead to a 93% comfort rate. This is a 13% increase from the fall 2017 study in which 80% of Pavilion responses were deemed as comfortable. The average air temperature inside the surveyed classrooms at the time of distribution was 75.2℉. This falls in the “not suitable for classes” range as defined in the 2018 KMC study. However, those temperatures were measured in empty classrooms, and it is reasonable to assume an increase in temperature during occupancy, and therefore it is not unreasonable to label 75℉ as an acceptable indoor air temperature for an occupied classroom.

Comfort at time of survey distribution

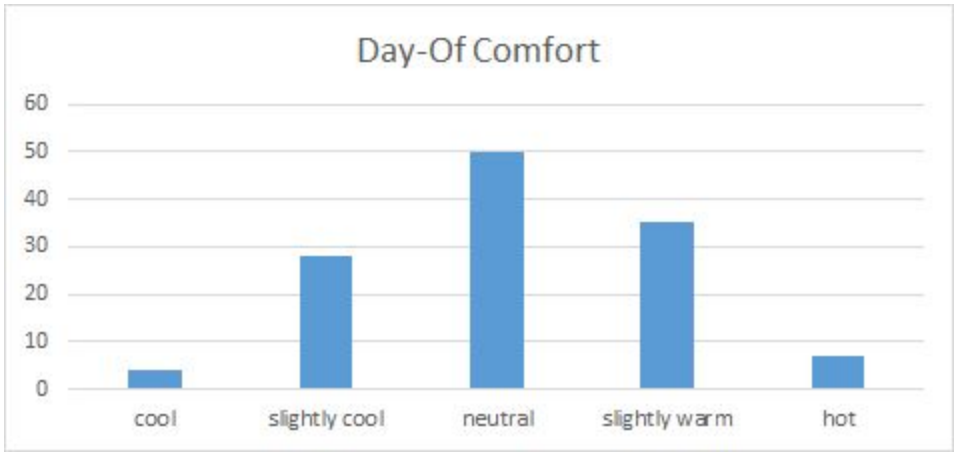

Figure 8. Overall Participant Comfort Levels at Time of Survey Distribution

Across the surveys, responses for thermal comfort at the time of execution followed a normal distribution, slightly weighted towards warmth as opposed to feeling cool. These responses will be analyzed on a room-by-room basis in the analysis section as there was a range of temperatures during the survey distribution process and a graphical representation of the entire sample may not provide all pertinent information.

Use of Wall-Mounted Controls

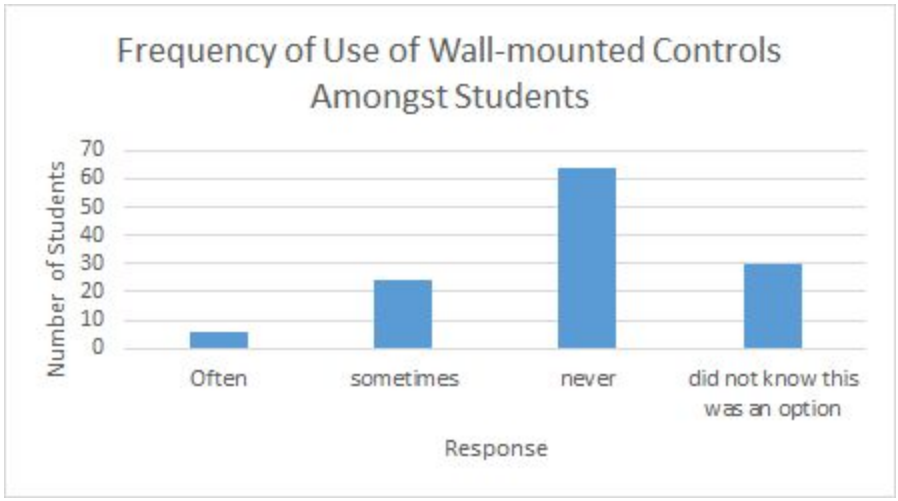

Figure 9. In-room Window and Ceiling Fan Control Use Frequency

When asked how often they used the wall-mounted controls for the windows and ceiling fans, most students had never used them, or did not even know it was an option. This presents an opportunity for occupant education as use of the controls is sometimes necessary to create a comfortable learning environment. This will be further discussed in the Analysis section of this study.

Air Quality Perception

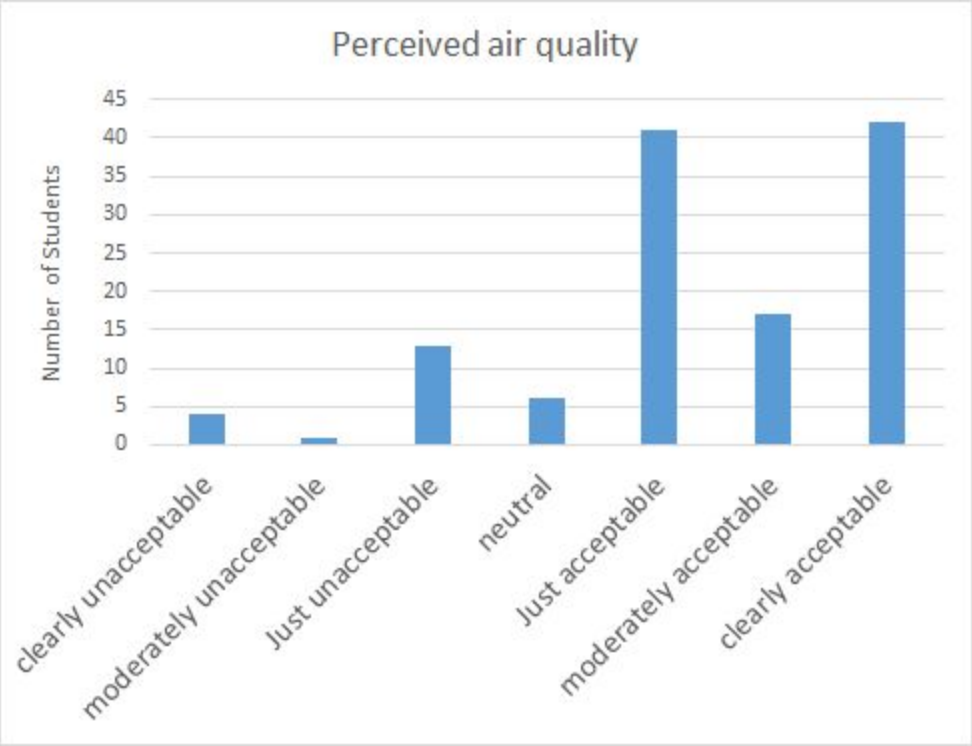

Figure 10. Air Quality Perception Amongst Survey Participants

Air quality is seen as acceptable by students, based on the 7-point sliding scale in the survey. It is unknown what effect the natural ventilation has on these survey results as students were not questioned about air quality in the renovated portion of the building.

Analysis

Determination of Ideal Pavilion Classrooms

One goal of this study is to update the existing scheduling protocol for summer classes in Pavilion spaces. The previous guideline was to take nearly all classrooms offline after 12pm in the summer with the exception of rooms 180 and 185. Unfortunately there is no one temperature where a majority of the population will experience overheating. Previous literature has shown the comfort band in naturally ventilated spaces is typically wider than for mechanically ventilated spaces.[2]

In order to prioritize classrooms for scheduling, a metric would need to be chosen for which all rooms could be compared. This study will look at the number of days experienced over a chosen temperature with more attention given to higher temperatures. This was chosen over the pure average approach because classes typically run between 8am and 8pm and it only takes one moment of a hot temperature to cause discomfort for a student. Therefore, even if a class was cooler than most for a part of the day but experienced a large spike, the rooms without large temperature variations would be chosen to hold classes.

Table 2. Number of days over a given temperature 6/10/2019-8/27/2019

	Temperature (F)					
Room	**75**	**76**	**77**	**78**	**79**	**80**
180	28	19	14	8	4	2
185	34	20	11	5	0	0
190	37	27	15	8	4	0
285	43	31	15	4	3	1
290	36	23	11	5	1	0
295	28	17	4	2	1	0
380	49	34	23	9	2	1
385	48	31	19	9	4	1
390	44	33	22	16	10	4
480	45	34	22	14	8	4

[2] "Thermal Comfort in Naturally Ventilated Buildings: Revisions to ASHRAE Standard 55 - ScienceDirect." Accessed September 4, 2019. https://www.sciencedirect.com/science/article/pii/S0378778802000051.

485	36	21	13	4	1	0
495	26	12	7	4	1	0
580	40	24	18	10	3	1
590	47	36	25	14	6	1

It is reasonable to aim for most classrooms to stay under 78℉, as cited by the pre-design study. However, it is unreasonable to expect a naturally ventilated space to stay within the usual range of a mechanically cooled space. Each room experienced at least 28 days over 75℉, the temperature deemed “unsuitable” by the summer 2018 researchers. However, some of these peaks occurred while the classrooms were occupied. Future analysis could investigate this further.

To rank the classrooms, temperatures were assigned a point value as listed below.

Table 3. Overheating Temperature Point Values

Temperature	75	76	77	78	79	80
Points	1	2	3	4	5	6

Then each time that temperature was exceeded, the corresponding number of points would be added to the room until all days and temperatures were accounted for.

Table 4. Final Pavilion Classroom Rankings

Room	Total Score	2019 Classes
295	87	1
495	92	1
185	127	4
485	138	1
290	140	5
180	172	4
285	187	4
190	188	2
580	203	2
385	229	2

380	238	3
590	286	1
480	299	2
390	314	1*

** denotes a limited class schedule, such as meeting a few days during the summer, and not the longevity of a typical summer term class.*

Through this method, 295 and 495 have emerged as the ideal classrooms. Neither of them experienced a day over 80℉ and experienced fewer days over nearly every other temperature as the remaining classrooms. Rooms 295 and 495 do share some architectural similarities. They are both on the eastern half of the Pavilion and neither have an east-facing window. Other classrooms in their position, such as 190 have large east-facing windows and tend to rise in temperature more quickly as the day progresses. Room 495 is unique in that it has windows on the north and south edifices.

Updates to 2018 Suitability Guidelines

Legend

Explanation	Color	Temperature (F)
Confident		T ≤ 73
Somewhat Confident		73 < T < 75
Likely to Receive Complaints		T ≥ 75

Table 1: **Average Temperatures** of Classrooms by Time of Day (7/15/18 - 8/15/18) per hour. (F)

Time	180	185	190	285	290	295	380	385	390	480	485	490	495	580	590
8:00 AM	71.0	71.1	71.7	72.5	72.0	72.0	73.7	74.4	74.1	72.9	73.4	72.8	73.2	73.5	73.4
9:00 AM	71.3	71.5	72.3	72.8	72.5	72.5	73.9	74.6	74.5	73.3	73.7	73.3	73.3	74.0	73.8
10:00 AM	71.5	71.7	73.0	73.0	72.7	72.9	74.2	74.7	74.8	73.6	74.1	74.0	74.2	74.2	74.2
11:00 AM	72.0	71.9	73.8	73.5	72.9	73.2	74.6	75.1	75.4	74.4	74.7	74.8	74.9	74.8	75.1
12:00 PM	72.2	72.0	74.1	74.0	73.2	73.4	74.9	75.3	76.1	75.1	75.2	75.7	75.2	75.3	75.7
1:00 PM	72.4	72.4	74.3	74.3	73.5	73.7	75.1	75.5	76.8	75.7	75.5	76.3	75.5	75.7	76.1
2:00 PM	72.5	72.7	74.3	74.5	73.7	73.8	75.4	75.9	77.1	76.3	75.6	77.0	75.9	76.2	76.7
3:00 PM	72.6	73.0	74.3	74.7	73.8	74.0	75.7	76.0	77.1	76.8	75.9	77.4	76.4	76.8	77.1
4:00 PM	72.7	73.0	74.3	74.9	73.9	74.0	75.9	76.1	77.0	77.3	76.0	78.0	76.6	77.3	77.5
5:00 PM	72.8	73.2	74.4	75.1	74.0	74.2	76.1	76.3	77.1	77.6	76.2	78.1	76.7	77.8	77.8
6:00 PM	73.1	73.1	74.7	75.6	74.2	74.3	76.3	76.6	77.0	77.7	76.5	78.0	76.8	78.1	77.9
7:00 PM	73.1	73.1	74.7	75.6	74.2	74.3	76.4	76.6	77.3	77.5	76.7	77.8	76.8	78.3	77.9
Average Temperature of Classroom	**72.3**	**72.4**	**73.8**	**74.2**	**73.4**	**73.5**	**75.2**	**75.6**	**76.2**	**75.7**	**75.3**	**76.1**	**75.5**	**76.0**	**76.1**

Total Seats	60	60	60	50	50	80	50	60	60	50	60		80	50	50
Maximum Recommended Occupants (70	42	42	42	35	35	56	35	42	42	35	42		56	35	35

Figure 11. Summer 2018 Hourly Temperature Averages for Pavilion Classrooms and Resulting Occupancy Suitability, derived from survey responses via renovated classrooms

	180	185	190	285	290	295	380	385	390	480	485	495	580	590
8:00 AM	72.2	72.9	72.3	72.4	73.2	72.2	73.6	73.9	73.8	72.7	72.8	72.3	72.8	72.7
9:00 AM	72.4	72.9	73.2	72.8	72.9	72.3	73.4	73.5	73.7	73.0	73.0	72.4	72.8	72.7
10:00 AM	72.2	72.3	73.6	72.7	73.2	72.3	73.2	73.7	73.8	73.0	72.8	72.1	72.4	73.3
11:00 AM	73.3	73.0	74.1	73.9	74.1	73.3	74.2	73.9	74.6	74.0	73.4	72.7	73.1	73.2
12:00 PM	74.5	73.6	74.7	74.2	74.3	73.7	75.0	74.4	75.4	74.6	74.2	73.3	73.9	73.8
1:00 PM	74.2	74.3	74.9	74.6	74.6	74.1	75.5	74.8	76.0	74.9	74.4	73.8	74.2	74.7
2:00 PM	74.1	74.8	75.5	74.9	74.9	74.3	75.8	75.2	76.3	75.3	74.6	74.1	75.0	75.5
3:00 PM	75.0	74.8	75.6	75.3	75.2	74.5	76.2	75.5	76.7	75.9	75.1	74.3	75.4	76.1
4:00 PM	75.3	75.2	75.7	75.5	75.5	74.9	76.4	75.8	76.6	76.2	75.3	74.8	75.9	76.4
5:00 PM	75.1	75.5	75.8	75.5	75.4	74.9	76.5	75.9	76.6	76.6	75.6	74.8	76.0	76.6
6:00 PM	75.2	75.4	76.2	76.0	75.7	74.9	76.5	76.2	76.6	76.9	75.8	75.0	76.3	76.8
7:00 PM	75.4	75.4	76.2	76.1	75.8	74.8	76.4	76.6	76.7	76.6	75.8	75.1	76.3	76.6
Average Temperature of Classroom	**74.1**	**74.2**	**74.8**	**74.5**	**74.6**	**73.9**	**75.2**	**75.0**	**75.6**	**75.0**	**74.4**	**73.7**	**74.5**	**74.9**

Figure 12. Summer 2019 Hourly Temperature Averages for Pavilion Classrooms and Resulting Occupancy Suitability, using 2018 comfort standards

A “suitability building diagram” was created to match that of the 2018 study. The same dates, time intervals, and classrooms were used. The biggest difference between the two years was the absence of active classes during the summer of 2018. The 2019 diagram shows overheating earlier in the day, although the averages for the rooms are not substantially different between years. The 2019 diagram also shows classrooms holding their lower temperatures for longer periods of time beginning in the morning, a possible indicator of more successful night flushes taking place. The elevation trend is not as evident in the 2019 diagram as in 2018. This could partially be explained by the increased occupancy on the lower floors of the building during the 2019 summer.

Figure 13. Summer 2018 Classroom Suitability Diagram

Figure 14. Summer 2019 Classroom Suitability Diagram

Once again, the elevation differences are not as drastic in the 2019 study as in the 2018 study. From the sidecut diagram it is easy to see the uniqueness of rooms 295 and 495. The exposure and cantilevered nature may play a role in their effective cooling properties. This could be an opportunity for further study in the future. Another notable change is the addition of 485 as a semi-suitable classroom. This may be tainted by 485 only hosting one class during summer 2019 term and the related absence of additional heating from occupants.

Night Purge Effectiveness

a. Focus

Initiation of investigating night purge effectiveness launched based on the facts that the window operation sometimes detected as a malfunction. As the passive cooling strategies on Pavilion supposed to control with precision of the window system, investigating the current night purge operation setting was inevitable. Normally, with the night purge ventilation technique, opening windows has to incorporate with a pre-set of time during the night in order to achieve effective cooling[3]. Throughout having a meeting with the Mechanical team of Facility and Property Management, the current system has a lack of sequence of operations for the extreme weather. Moreover, the highest temperature drop was observed a maximum of 3℉ during this summer.

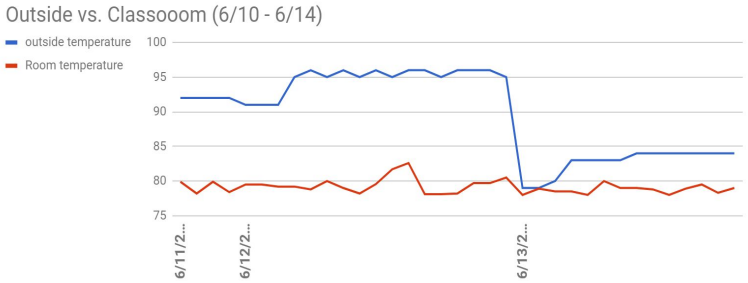

Figure 15. Comparison of indoor vs. outdoor temperatures from June 11th to June 14th.

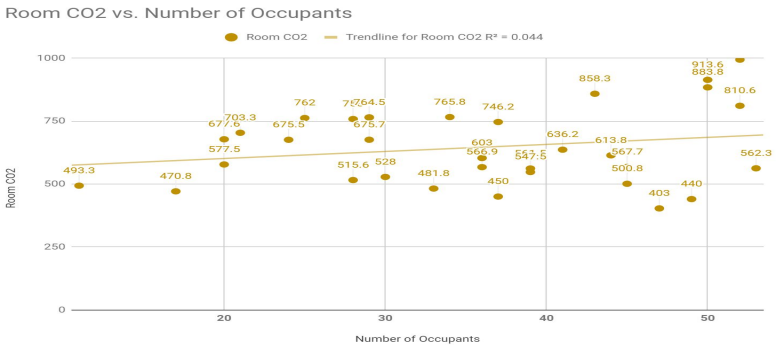

Figure 16. A linear graph of CO2 levels depend on the number of occupants from June 11th to June 14th.

b. Temperature

According to the temperature data, the hottest days of the summer were in the final week of the Spring term. In the period between June 10th to 14th, the temperature of a Pavilion classroom

[3] "Mixed-mode buildings: A double standard in occupants' comfort expectations."Accepted January 24, 2012.

frequently exceeded the comfort band(76℉-83℉), and the temperature of room 480 has reached 82.6℉ on June 12th. As the temperature analysis pointed out above, these temperatures are often typical in Portland summer season.

c. Data collection techniques

Currently, Siemens Insight employed to control the window operation, and the night purge operation is occurred by detection of temperature difference, not set by time. In the final week, we collected the temperature and CO2 levels from BAS and analyzed temperature changing after windows open for night purge with the current setting. The current setting for night purge is opening windows when classroom temperature reached 72℉. In addition to the last year research of Omar and Jocelyn, the night purge effectiveness with the thermal mass of the concrete slab was observed as the average of 0.94℉.

Schedule	Night purge		outdoors temperature			Average before night purge (2 hours)		Average after night purge (2 hours)		Averge drop-in	
date	time	duration	initial	final	outdoor	temperature	CO2	temperature	CO2	temperature after night purge	CO2 after night purge
6/11	7:30:00	30	68	71	-3	70.16	456	70.81	435	-0.65	21.0
6/12	7:00:00	30	72	76	-4	72.93	478	72.72	455	0.21	23.0
6/13	20:00:00	60	87	83	4	76.14	401	74.19	401	1.95	0.0
6/14	20:00:00	60	65	63	2	70.59	385	69.8	385	0.79	0.0

Figure 17. Temperature drops in the final week

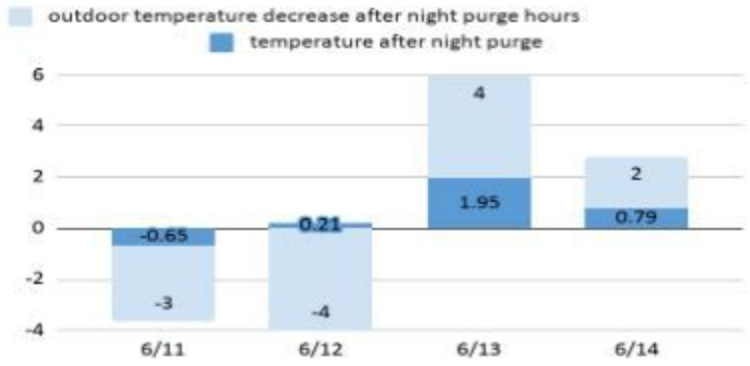

Figure 18. Night purge effectiveness related to outdoor temperature

d. Actual monitoring

Figure 17 represents the outcomes from BAS weekly reports. Each day of night purge operation was considered when all Pavilion classroom windows ordered as "Open" in a certain period of

hours. The shortest was 30 minutes and the longest was 90 minutes. Under the system override on window opening, the drop rate of temperature and CO2 were calculated as an average value of total running hours, which is ranged from 2 hours before night purge, running hours, and 2 hours after night purge. According to the final measurements, the average temperature drop was 0.58℉ and it estimated as lower than measurements of last year.

Theoretically, the temperature of the classrooms can release their heat when the outdoor air temperature is lower than the indoor air temperature. In this period, however, night purges occurred even though there is no gap between outdoor air temperature and indoor air temperature. Ventilation studies of Mixed-mode building from Center for Built Environment suggest that 3 - 5 ℃ gaps will bring more cool air in during night purge operation in the summer season. In this week, night purges occurred at 7:30 am on June 11st, 7:00 am on June 12nd, 20:00 pm June 13th, and 20:00 pm June 14th. Secondly, there was no report on indoor air-velocity to analyze the fluctuation of ventilation rates. We only expected there were enough air-velocity to releasing heats and indoor pollutants by tracking the drop rates of temperature and CO2 level in BAS.

e. Perception

Throughout analyzing the effectiveness of current night purge setpoints and outcomes, we were able to briefly collect the opinions of professors to correlate the occupant's thermal comfort to temperatures after night purge operations. The list of professors was selected based on their class schedule on the final week and the number of occupied students. During this survey, 13 professors responded among 35 professors and mostly answered the temperature was slightly warm or warm among the other five variations but they agreed on it was bearable with turning ceiling fans and opening windows.

Even though the reported temperature data and occupants satisfaction level were matched to the comfort range, a concern about the noisy was commonly pointed out that it can be a source of distracting class activities. The type of noises was varied from outdoor traffics to scratching sounds of window motions. Additionally, comments on the wall-mounted controller were reported throughout this survey that the instruction is required for use.

f. SImulation

Simulation for evaluating the night purge effectiveness on releasing heats and CO2 levels is done by planning 4 different sequences of operations with utilizing the sources. The sources that utilized for this simulation were selected based on the criteria which meet the low energy use performance and no extra adding on the facility. In the design stage, Jason Luce, Mechanical engineer in FPM cooperated to build the 4 different sequences.

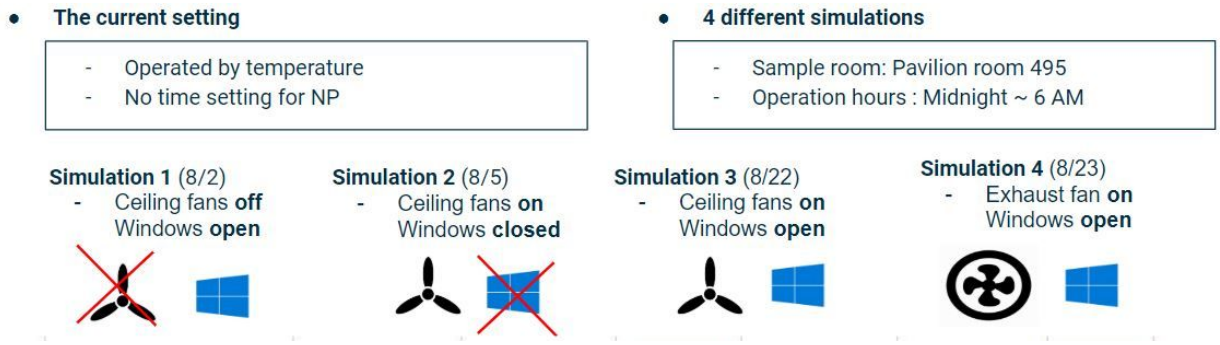

Figure 19. Simulation with 4 different sequences

In order to achieve the objective of this simulation, readings of BAS report are conducted on the sample of the classroom in Pavilion, which is Room 495. With the location setting, the 4 different individual sequences were planned at a different day, and those days share similar outdoor settings. Climatically, night flushing is only suitable for climates with a relatively large temperature range from day to night, where nighttime temperatures are below 68 or 71°F. Accordingly, nighttimes between midnight to 6:00 AM of Aug 2nd, August 5th, August 22nd, and August 23rd were chosen to be conducted for this simulation. Followed, actual readings and simulation values were obtained in the same way as we measured from the final week of Spring term.

The first simulation, conducted on August 2nd has a similar set to the current setting but conducted from Midnight to 6:00 Am which running time applied similarly to the other three simulations. The second simulation utilized ceiling fans without opening windows, and the third simulation have both ceiling fans and windows support to see how the ventilation rates increased but we did not measure air-velocity due to a lack of capacity. Finally, the last simulation is operated by turning an exhaust fan(AHU-003) while windows open.

Simulation	Outdoor initial	Outdoor final	Outdoor drop-in	Room initial	Room final	Room drop-in
Option 1 (windows only)	69	66	3	74.91	75.67	-0.76
Option 2 (Ceiling fans only)	71	65	6	74.66	71.24	3.42
Option 3 (Ceiling fans & windows)	60	58	2	71.6	70.59	1.01
Option 4 (exhaust fans & windows)	61	58	3	71.82	69.76	2.06

Figure 20. final results

h. Final results

The effectiveness of night purge was observed to success in releasing heat and CO2 level, and comments on thermal dis-satisfactions were commonly related to students feeling that they did not have enough control over their environment. In addition to complaints about thermal comfort, most professors responded it was bearable even though the classroom temperature sometimes reached to 80. However, opening windows only for night purging is measured as ineffective in terms of releasing heat. Moreover, in hot days, we assume that opening windows with ceiling fans support or exhaust fan support will bring more temperature dropdown. Even though the simulation did not measured the air-velocity, we collected the other data to measure the effectiveness of releasing heat and reducing the CO2 levels in the classrooms. Therefore, we recommend developing option 3, 4 with other data by air-velocity measurement and energy usage difference to develop a new setpoint for night purging in hot days. Moreover, occupants who have responded to the online survey provided this research very useful cues to understand how the building is working not just at their individual, but for the building as a whole. When we consider the main occupants are mostly faculty members who have their office area in Renovated side, their qualitative opinions will bring more benefits to analyze. Furthermore, as we observed the operational complaints have been started to report from this year, future research should survey for their occupational experiences to identify the relationship between the mechanical and natural systems as a whole.

Providing students and faculty with a quality indoor environment should be a goal of any building design, but is particularly important for this green building that claims to be more responsive to supporting occupant comfort level, and productivity. A combination of the

diagnosis on the current setpoints, surveys, and the simulation suggests that there is the greatest benefit in utilizing the wall-mounted controller to increase the effectiveness of night purge. In the next summer research, as we move toward embracing high-performance, we must also insist that post-occupancy evaluation on Pavilion, Atrium and Renovated sides will be a natural part of the process.

Survey Analysis

Thermal Comfort

On the day of the survey, students reported nearly equal “slightly cool” and “slightly warm” answers. Of course, this is difficult to analyze as a whole because of the variability in days and classrooms. As an example:

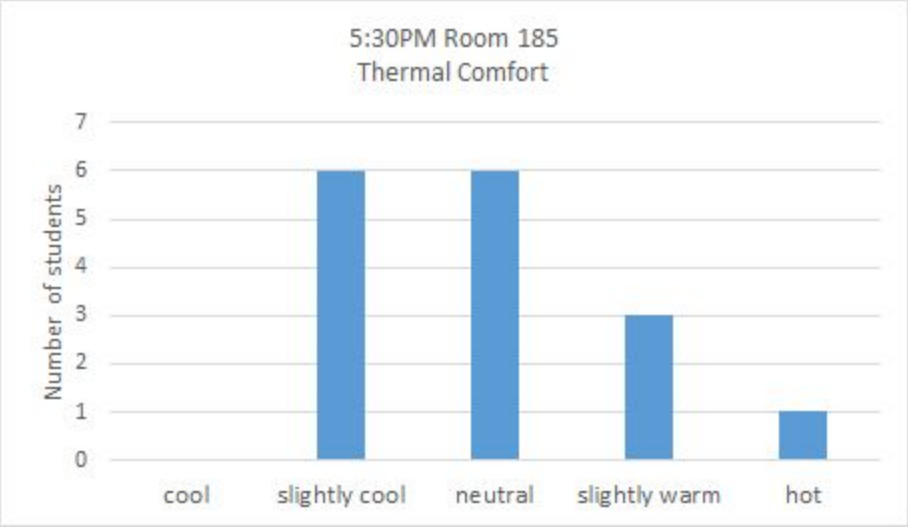

Figure 21. Survey 2: Room 185, Thermal Comfort Responses at 5:30pm. Outdoor Temperature: 80℉, Indoor Temperature: 75℉

The outdoor temperature during this evening class was 80℉. Oddly, a large number of students felt slightly cool in the classroom. This can be compared with a morning class with only a two-degree indoor temperature increase, as it was 77F in the morning class and 75F in the evening class.

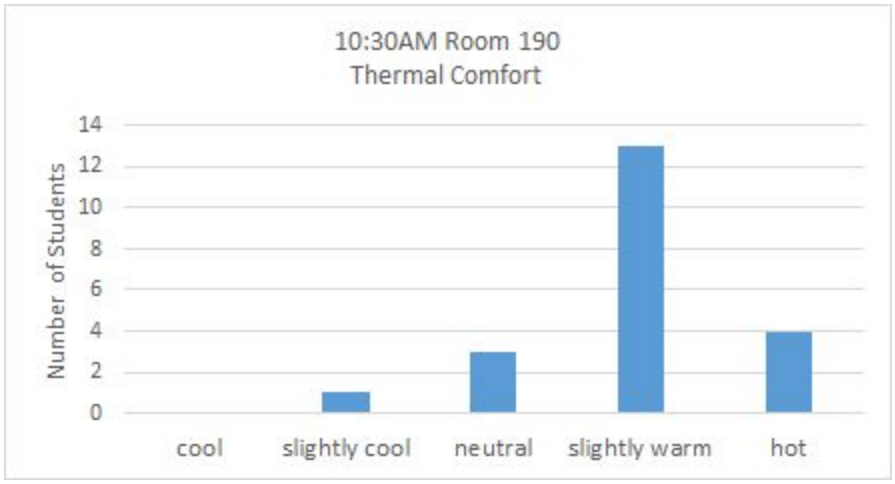

Figure 22. Survey 5: Room 190, Thermal Comfort Responses at 10:30AM. Outdoor Temperature: 77℉, Indoor Temperature: 77℉

Nearly all students in this class reported feeling slightly warm. Upon entering the classroom, the researchers noticed the windows were closed and the ceiling fans were not turned on. With the windows open and ceiling fans operating, the interior comfort level increased, not just as noted by the researchers, but also verbally from students in the class.

Classroom variability is important in the KMC as certain rooms have large east-facing glass windows, leading to increased morning sun exposure, while others may have windows on two sides of the room, compared to just one set of windows for most Pavilion classrooms. Elevation also makes a difference, as the classrooms on the top three floors tended to experience more frequent overheating compared with those on the first and second floors. This is due to the stack effect in which warmer air will migrate upwards in the building due to pressure differences as the day progresses.

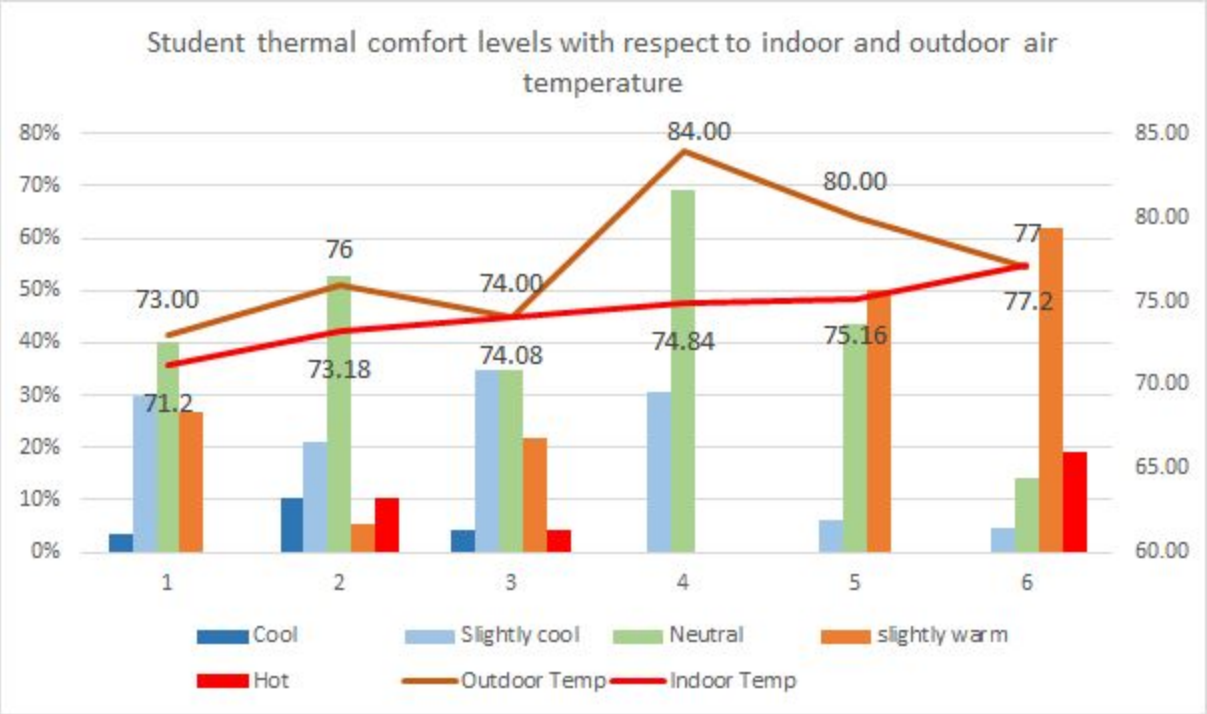

Figure 23. Aggregate survey responses versus indoor and outdoor air temperature at the time of survey distributions

It is difficult to find trends between indoor air temperature and comfort levels, at least within the temperature range of 71-77℉. The most obvious temperature limit arises above 75℉, where the number of warm and hot responses outnumber the neutral and cool responses. Below 75℉, the responses follow a normal distribution. One can assume this is representative of general occupant comfort.

The upper limit of 75℉ is consistent with the 2018 results, with the exception that few students reported actual overheating at temperatures as high as 77℉. If the building is seeking to be optimized for maximum possible classroom use, 77℉ could be used as the upper limit. This is still lower than the pre-design study that listed 78℉ as the limit in the absence of overhead fans. Each room in the KMC Pavilion is equipped with overhead ceiling fans, ideally raising the overheating temperature past previous expectations.

Use of Integrated Window and Ceiling Fan Controls

As noted in Figure 9 (Raw Data/Results) the user controls in the Pavilion classrooms are largely underutilized by students. 52% of surveyed students have never used the controls, and another 25% did not even know they existed. Use of the ceiling fans can raise the upper limit of the comfort band up to 84℉, up from 78℉, according to the 2015 Pre-Design study cited earlier, therefore it is crucial that all occupants are aware of their presence and more importantly, how to use them properly.

Moving forward, the PSU Campus Planning office will work with Capital Projects and Construction (CPC) as well as Facilities and Property Management (FPM) to address the education issue regarding the controls. The most likely remedy will be a small poster displayed in every Pavilion classroom above each of the control modules. A possible draft version is displayed below.

Figure 24. Draft of In-Class Control Instructions

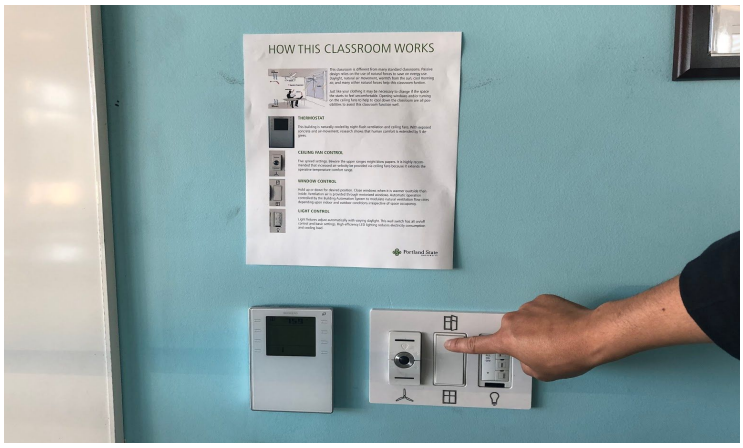

Figure 25. In-class control system during window opening

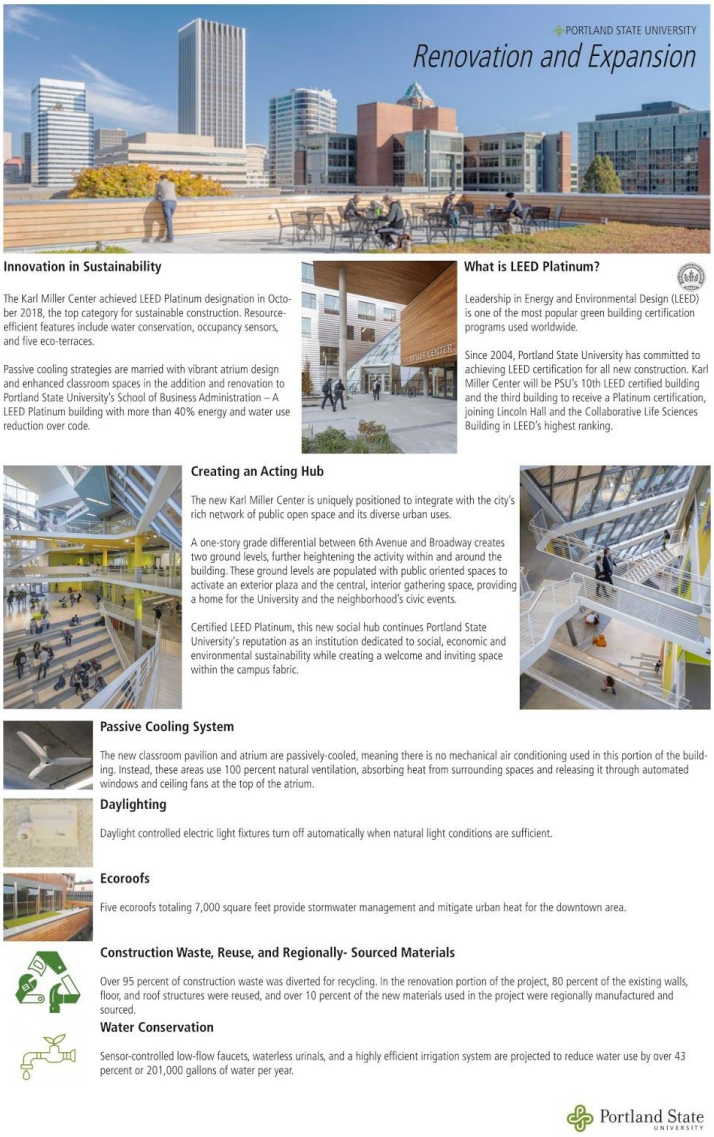

Figure 26. In-class control system during window opening

In addition, a training video may be produced by FPM to further educate faculty. This will all take place after the conclusion of this research project and its effectiveness could be evaluated by future studies.

However, it is not sufficient to only know how to tailor the indoor environment of the Pavilion via the wall-mounted controls. Knowledge of the building processes and their environmental benefits may have an effect on student and faculty comfort levels. If they are informed of the

energy savings of the building as a result of the natural ventilation, it is possible their personal comfort range may widen as they could be more willing to be slightly uncomfortable if they know they are being part of a sustainable solution. This increased education could be achieved via increased signage, including the use of monitors that exist outside the elevators on the renovated portion of the KMC.

Inspiration could be drawn further from the SEA-TAC (Seattle) airport in which its new features are on display via signage on pillars and monitors, similar to those in the KMC.

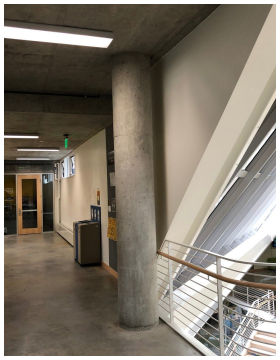

Figure 27. SEA-TAC Information System

Figure 28. KMC Information Opportunities

Conclusion

The KMC is performing as intended by the design proposal. Summer interior air temperatures stayed below those outlined in the 2015 pre-design study on average. Survey responses indicated that students are generally comfortable in KMC Pavilion classrooms, with 93% of students reporting answers registering as acceptable. In order to maintain or improve upon this rate of satisfaction, it is imperative the in-room window and ceiling fan controls are optimized. Currently, most students and faculty and unaware of the potential comfort improvements the controls aid. As of the conclusion of this study, a plan is in motion to increase user awareness through increased signage and possible other means. An additional opportunity exists to cool

the building through an enhanced night flush procedure in which the rooftop exhaust fans are turned on during nighttime hours to draw additional cooler air into the building. However this will need to be evaluated on an energy-use basis as well due to the building having achieved LEED Platinum status and PSU's sustainability goals. A long term air quality monitoring deployment was completed as part of this study. Results can be expected in the year 2020 and analysis will likely be performed through the Green Building Research Laboratory.

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Appendices

Appendix A: KMC Indoor/Outdoor Temperatures

Table A1. Maximum Daily KMC Pavilion Classroom Air Temperatures

Date	180	185	190	285	290	295	380	385	390	480	485	495	580	590
6/10/2019	73.72	75.02	76.64	76.06	75.92	75.85	76.42	77.79	78.08	77.76	74.52	75.27	74.26	75.49
6/11/2019	77.43	77.54	77.47	77.68	77.4	76.96	78.48	81.28	80.31	80.2	77.72	78.33	76.6	79.23
6/12/2019	81.07	78.4	78.98	80.74	78.08	78.69	80.2	79.56	82.04	83.12	78.3	79.41	80.24	82.04

6/13/2019	78.66	78.04	79.34	79.56	78.37	79.66	79.84	79.12	80.82	79.66	79.27	78.48	78.51	79.41
6/14/2019	73.18	75.02	73.58	74.19	75.27	73.4	75.27	75.24	75.2	74.84	74.84	73.83	74.05	77.25
6/15/2019														
6/16/2019	73.04	74.23	74.77	77.94	76.14	76.03	76.39	75.45	76.35	76.53	75.99	74.77	76.21	77.11
6/17/2019	73.33	76.42	75.16	77.36	76.24	73.76	76.21	75.96	76.24	76.14	75.74	74.7	75.49	77.5
6/18/2019	72.21	74.84	73.11	73.33	74.95	73.69	74.62	74.16	73.44	72.97	73.04	72.54	73.04	75.96
6/19/2019	71.24	75.02	71.92	73.29	73.11	71.92	73.62	72.46	72.36	73.26	71.89	71.28	72	73.47
6/20/2019	70.7	74.98	72	73.94	73.15	72.39	73.04	72.28	71.46	72.21	71.17	70.92	71.17	73.9
6/21/2019	70.7	73.62	73.26	72.75	73.87	71.82	73.04	71.82	72.21	72.1	71.38	70.56	70.99	73.8
6/22/2019	70.84	72.75	71.42	72.46	73.9	71.2	73.44	72.18	71.13	72.61	71.78	72.14	71.49	72.64
6/23/2019	70.52	72.46	70.92	73.22	72.25	72.32	73.18	71.78	71.56	72.14	71.42	70.81	71.46	73.36
6/24/2019	73.62	72.18	71.24	73.29	72.18	71.96	74.84	74.08	71.56	71.74	71.28	71.38	70.92	72.21
6/25/2019	72.21	73.15	72.72	73.87	72.86	71.78	75.2	74.05	72.46	73.11	72.39	71.96	73.26	73.08
6/26/2019	73.51	73.29	73.69	74.12	73.62	71.31	74.62	73.65	72.9	73.33	72.39	72.68	72.1	73.69
6/27/2019	71.38	72.07	72	72.18	71.78	72.14	74.98	72.39	71.35	72	71.46	72.61	74.16	70.66
6/28/2019	71.35	72	75.16	72.64	71.42	70.52	73.15	73.98	72.1	72.57	71.46	70.84	71.92	73.29
6/29/2019	71.42	72.39	74.88	75.49	74.19	71.28	74.34	73.62	73.94	73.51	72.97	71.82	72.82	74.08
6/30/2019	72.07	73.18	76.35	74.26	73.22	72.1	74.88	73.8	74.95	75.49	73.65	72.21	73.69	75.02
7/1/2019	75.13	73.72	74.73	75.6	75.38	74.77	75.67	76.46	76.14	75.31	74.23	73.98	74.37	76.14
7/2/2019	72.36	73.44	72	73.26	74.08	72.68	74.37	74.95	72.18	72.9	73.29	71.64	73	74.08
7/3/2019	71.74	73.8	73.51	72.97	72.64	71.92	74.12	73.87	72.1	73.04	72.82	71.46	71.85	74.52

7/4/2019	72.25	73.4	74.62	74.8	73.33	72.28	74.48	75.49	74.55	75.49	74.12	72.5	73.58	76.06
7/5/2019	71.06	72.18	72.46	73.72	72.36	71.17	75.27	73.58	72.75	73.76	73.15	71.64	72.86	72.68
7/6/2019	70.88	70.81	72.21	73.4	71.42	70.74	74.23	72.72	71.6	72.82	71.85	70.84	71.2	72.03
7/7/2019	71.1	72.07	73.15	73.47	72.21	71.82	74.41	73.18	71.78	73.72	73.08	71.82	73.18	71.46
7/8/2019	75.63	72.5	73.4	75.34	73.04	71.92	75.06	75.74	75.2	74.37	73.15	72.93	73.65	72.54
7/9/2019	71.6	74.05	74.55	74.84	72.97	73.76	74.23	73.87	76.32	74.62	72.5	73.54	74.66	71.67
7/10/2019	74.95	74.34	74.37	74.62	74.26	72.1	74.8	75.16	74.77	75.2	74.16	73.04	73.44	73.62
7/11/2019	74.55	73.69	74.73	76.03	74.55	74.26	77.65	76.5	75.31	75.74	75.38	73.76	76.68	74.52
7/12/2019	73.04	73.98	74.12	74.66	75.6	73.26	76.6	75.45	76.6	76.5	75.13	73.4	75.38	75.34
7/13/2019	73.33	74.12	74.98	76.64	74.95	75.85	76.78	75.92	76.5	76.78	75.78	74.7	75.7	75.13
7/14/2019	73.33	74.16	75.49	75.6	74.88	74.23	76.82	76.03	77.58	77.22	75.7	74.73	75.99	75.88
7/15/2019	77.04	74.95	75.06	76.6	75.2	75.02	76.03	78.19	76.14	75.38	75.92	74.44	75.34	75.38
7/16/2019	76.96	76.57	75.81	76.96	75.88	75.45	77.14	76.71	76.42	76.96	75.99	75.16	76.89	76.82
7/17/2019	75.78	75.24	76.1	76.42	76.24	74.08	75.99	76.68	75.74	76.53	74.52	74.48	75.02	76.24
7/18/2019	74.44	74.8	75.42	76.03	74.66	75.38	75.99	75.99	75.78	75.13	74.84	74.16	75.78	76.64
7/19/2019	73.22	74.73	74.77	74.73	74.23	73.18	75.13	75.85	75.67	74.26	74.37	74.05	74.37	76.32
7/20/2019	73.04	74.62	76.53	74.88	74.44	73.72	75.85	75.13	75.99	76.53	75.34	74.48	75.78	77.07
7/21/2019	73.87	75.24	77.29	75.78	75.52	74.84	76.64	76.21	78.04	78.66	76.78	75.42	77.97	78.22
7/22/2019	78.94	76.35	76.53	76.35	77.22	74.66	77.32	76.17	79.45	77.47	77.11	75.49	77.22	78.04
7/23/2019	75.06	75.7	76.24	75.42	75.99	74.3	76.46	76.21	75.24	76.17	75.99	74.08	75.74	74.26
7/24/2019	77.11	75.88	76.21	77.25	76.06	73.94	77.14	76.96	77	76.32	75.88	74.34	75.52	76.96

7/25/2019	76.53	76.6	77.43	77.47	77.22	76.32	78.19	78.12	79.16	78.12	77	75.2	77.97	78.91
7/26/2019	78.19	76.82	78.04	76.75	76.89	76.06	78.66	77.72	79.59	80.1	78.01	76.24	78.08	79.34
7/27/2019	74.91	75.09	76.39	76.17	75.49	76.6	77.68	76.75	76.96	77.29	76.39	75.02	77.14	76.39
7/28/2019	74.62	78.58	77	76.75	75.13	75.45	77.11	77.07	77.43	77.68	76.6	75.38	77	77.14
7/29/2019	78.91	76.21	77.14	78.44	76.64	77.18	77.79	76.86	77.36	77.43	76.6	75.42	77.97	78.84
7/30/2019	76.6	77.58	76.42	76.42	76.53	76.39	77.36	77.47	78.22	77.5	77.4	75.85	78.62	77.25
7/31/2019	79.52	78.22	78.44	77.72	77.22	76.53	78.3	77.14	78.3	79.16	77.11	75.78	78.15	78.76
8/1/2019	77.5	78.08	79.16	79.2	79.95	77.9	78.76	78.8	79.52	79.84	77.65	77.04	79.27	77.4
8/2/2019	75.42	75.96	76.32	77.25	77	76.68	77.79	77.83	77.4	77.65	77.29	74.98	77.9	77.72
8/3/2019	75.13	75.88	76.68	76.6	76.42	76.03	77.4	77.47	77.86	78.4	76.93	77	78.55	78.01
8/4/2019	75.67	76.57	78.26	77.36	77.18	76.53	77.86	78.26	79.09	80.2	78.62	77.18	79.34	79.84
8/5/2019	80.31	77.47	77.58	77.5	76.93	76.39	78.19	78.69	79.02	79.05	77.58	76.82	78.76	79.34
8/6/2019	79.09	77.65	79.02	77.83	78.66	76.75	78.12	79.52	80.53	78.51	77.43	77.97	78.76	77.65
8/7/2019	76.24	75.38	75.09	75.99	76.32	75.13	75.88	75.7	74.91	75.6	75.49	75.63	75.56	77.36
8/8/2019	75.2	75.16	74.44	74.37	75.02	73.76	75.42	75.49	75.88	74.41	73.94	73.76	73.9	76.17
8/9/2019	74.23	75.31	75.31	75.96	75.92	74.48	76.1	75.78	75.67	75.34	75.67	74.88	75.81	77.4
8/10/2019	74.26	74.59	74.41	75.78	74.73	75.63	75.78	75.7	74.73	74.8	75.09	74.8	74.26	75.78
8/11/2019	73.62	74.23	74.19	75.99	74.44	74.55	75.85	75.06	74.48	74.88	74.7	74.37	75.56	75.24
8/12/2019	77.18	75.92	75.96	76.17	76.14	73.98	76.71	76.6	75.92	76.24	75.88	75.88	75.99	75.96
8/13/2019	76.75	77.07	77.86	77	78.15	76.32	77.47	77.22	78.87	78.91	76.24	76.71	77.14	78.58
8/14/2019	77.97	77.36	79.09	77.65	77.47	75.7	77.9	77.11	78.3	78.8	77.65	78.37	77.4	78.3

8/15/2019	75.34	76.03	77.65	76.53	75.52	75.67	77.18	77.94	77.54	76.86	76.14	76.32	76.53	76.53
8/16/2019	73.72	73.98	74.34	74.55	74.48	74.05	75.38	75.31	74.16	75.02	74.91	75.56	75.02	72.32
8/17/2019	71.96	73.33		72.75	72.46	72.5	73.22		70.63	72.72	72.21	72.97	72.75	72.21
8/18/2019	73.4	72.54	72.32	73.54	72.9	72.32	74.37	73.4	73	73.4	73.4	73.72	74.01	74.48
8/19/2019	72.32	73.22	75.78	73.4	73.44	73.98	74.62	73.69	73.9	74.34	73.4	74.88	74.19	75.27
8/20/2019	74.7	76.14	74.98	75.56	74.55	75.24	75.2	73.76	76.53	76.28	74.55	75.49	75.13	76.5
8/21/2019	72.86	73.51	72.86	73.18	73.69	72.28	72.86	73.29	71.71	73	72.93	73.54	72.9	74.88
8/22/2019	73.87	73.58	72.72	71.49	71.35	72.21	73.62	73.58	74.55	73.4	73.33	73.69	73.69	74.88
8/23/2019	72.57	73.26	73.22	75.31	73.9	72.14	74.55	73.65	73.69	74.52	73.4	72.43	74.34	74.26
8/24/2019	74.95	73.69	73.62	73.76	73.4	74.12	74.95	73.8	74.34	75.56	73.72	73.47	74.91	74.37

Table A2. Daily Outdoor Dry Bulb Temperature Summaries for Portland, OR - 2019 (National Weather Service)

Date	Maximum	Minimum	Average
6/1/2019	81	54	67.5
6/2/2019	80	53	66.5
6/3/2019	74	52	63
6/4/2019	79	50	64.5
6/5/2019	67	56	61.5
6/6/2019	65	52	58.5
6/7/2019	61	50	55.5
6/8/2019	69	52	60.5
6/9/2019	82	51	66.5
6/10/2019	86	58	72
6/11/2019	97	60	78.5
6/12/2019	98	68	83
6/13/2019	85	57	71
6/14/2019	73	56	64.5

6/15/2019	80	56	68
6/16/2019	82	54	68
6/17/2019	81	58	69.5
6/18/2019	73	55	64
6/19/2019	70	54	62
6/20/2019	69	54	61.5
6/21/2019	70	56	63
6/22/2019	73	55	64
6/23/2019	71	55	63
6/24/2019	72	51	61.5
6/25/2019	75	55	65
6/26/2019	77	56	66.5
6/27/2019	65	54	59.5
6/28/2019	75	51	63
6/29/2019	82	54	68
6/30/2019	85	56	70.5
7/1/2019	81	60	70.5
7/2/2019	68	60	64
7/3/2019	72	60	66
7/4/2019	80	58	69
7/5/2019	76	59	67.5
7/6/2019	68	58	63
7/7/2019	74	56	65
7/8/2019	78	58	68
7/9/2019	75	61	68
7/10/2019	77	63	70
7/11/2019	81	64	72.5
7/12/2019	84	61	72.5
7/13/2019	81	63	72
7/14/2019	85	62	73.5
7/15/2019	77	64	70.5
7/16/2019	82	65	73.5
7/17/2019	75	63	69
7/18/2019	76	60	68

7/19/2019	77	55	66
7/20/2019	88	57	72.5
7/21/2019	91	58	74.5
7/22/2019	86	61	73.5
7/23/2019	78	61	69.5
7/24/2019	82	55	68.5
7/25/2019	91	58	74.5
7/26/2019	92	65	78.5
7/27/2019	80	64	72
7/28/2019	85	60	72.5
7/29/2019	83	60	71.5
7/30/2019	80	60	70
7/31/2019	87	60	73.5
8/1/2019	90	61	75.5
8/2/2019	80	65	72.5
8/3/2019	88	64	76
8/4/2019	94	64	79
8/5/2019	91	65	78
8/6/2019	85	61	73
8/7/2019	73	61	67
8/8/2019	71	64	67.5
8/9/2019	77	64	70.5
8/10/2019	77	62	69.5
8/11/2019	76	62	69
8/12/2019	83	59	71
8/13/2019	90	60	75
8/14/2019	87	64	75.5
8/15/2019	83	61	72
8/16/2019	77	60	68.5
8/17/2019	72	60	66
8/18/2019	77	58	67.5
8/19/2019	81	60	70.5
8/20/2019	86	58	72
8/21/2019	73	60	66.5

8/22/2019	75	55	65
8/23/2019	84	56	70
8/24/2019	82	59	70.5

Appendix B: Survey Information

KMC Survey Consent Form

Participant,

Taking part in this survey is completely voluntary. All survey results are anonymous. It is in your right to deny, refuse, and/or discontinue participation at any time with no penalty or loss of benefits.

This study includes research and data conducted on how the design of the Karl Miller Center's new addition and remodel affects the level of occupant comfort in the building. This study is in partnership with PSU's Institute for Sustainable Solutions Living Lab (ISS) Program, PSU Capital Projects and Construction (CPC), the School of Architecture's Building Science Lab to Advance Teaching (BUILT), and the School of Business.

During this project, we will analyze ventilation design performance versus occupant comfort. Our research specifically focuses on how passive architecture reduces the need for conventional HVAC systems. Passive architecture is a design strategy that uses climate, orientation, and the location of a building to optimize natural environmental conditions to improve comfort.

If you have any questions, concerns, or complaints feel free to email us:

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Junyoung Lee
junyoung@pdx.edu

If you wish to contact our supervisor with questions, concerns, or complaints about the research; questions about the subjects' rights; to obtain information or to offer input, please contact:

Capital Projects and Construction - Technical Services Manager
Quinn Soifer
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Campus Sustainability Office - Education and Outreach Coordinator
Emily Quinton
equinton@pdx.edu

Karl Miller Center Comfort Survey - Summer 2019

1. Please **circle** the option that best includes your class period

   8:00am-1:00pm 1:00pm-4:30pm After 4:30pm

2. From your experience this summer, how thermally comfortable are you in this room? **Circle** one.

   Very uncomfortable Slightly uncomfortable Neutral Slightly comfortable Very comfortable

3. Please **circle** the thermal comfort level in the classroom that best describes your situation **today.**

   Cold Slightly cool Neutral Slightly warm Hot

4. Have you personally used the wall-mounted controls for the windows or ceiling fans anywhere in this building?

   Often Sometimes Never Did not know this was an option

5. In your opinion, how would you describe the air quality in the classroom with relation to freshness, smells, etc.? **Please write an "x" anywhere on the scale below**

   |_____|_____|_____|

   Clearly Unacceptable Just Unacceptable Just Acceptable Clearly Acceptable

6. How have you been informed about the sustainability features of this building?
   - ❑ Professor
   - ❑ Building operator(s)
   - ❑ Sustainability Office
   - ❑ Other:_____
   - ❑ I am uninformed about the sustainable features of this building.

7. Please provide any comments you have regarding your general comfort in this classroom

Appendix C: Survey Results

Table C1. Survey 1: KMC 185, 5:30pm, Outdoor Temperature: 74.0, Indoor Temperature: 74.08

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Slightly uncomfortable	neutral	never	neutral	I am uninformed about the sustainable features of this building	-
2	Very uncomfortable	slightly warm	sometimes	clearly unacceptable	I am uninformed about the sustainable features of this building	The air circulation and air conditioning in this building is poor. On multiple occations I have been unable to focus
3	Neutral	slightly warm	never	moderately acceptable	Professor	
4	Slightly uncomfortable	slightly cool	Often	Just acceptable	I am uninformed about the sustainable features of this building	I cannot stand how the windows opend on their own when the room is too warm
5	Slightly comfortable	neutral	sometimes	clearly acceptable	Professor	
6	Slightly comfortable	slightly warm	never	moderately acceptable	Professor	Need more infor about thow to open the fans/windows would be useful. Have had multiple porfs who did not know how to adjust them
7	Slightly uncomfortable	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	The auto wall-mounted controls don't seem well regulated or set ... it often gets way too warms and stuffy

8	Very comfortable	neutral	never	clearly acceptable	I am uninformed about the sustainable features of this building	
9	Very comfortable	neutral	never	clearly acceptable	#N/A	
10	Neutral	slightly warm	never	Just acceptable	Professor	
11	Neutral	slightly warm	never	clearly acceptable	I am uninformed about the sustainable features of this building	The automatic windows are very loud + distracting
12	Slightly comfortable	slightly warm	never	clearly acceptable	I am uninformed about the sustainable features of this building	
13	Neutral	slightly warm	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
14	Slightly comfortable	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	
15	Neutral	neutral	never	neutral	I am uninformed about the sustainable features of this building	
16	Slightly comfortable	slightly warm	never	Just acceptable	I am uninformed about the sustainable features of this building	
17	Slightly comfortable	slightly warm	sometimes	Just acceptable	#N/A	
18	Neutral	neutral	never	moderately acceptable	I am uninformed about the sustainable features of this building	
19	Neutral	slightly cool	sometimes	clearly acceptable	Professor	The new building is certainly an upgraded compared to the other. Its nice, open, and well structured

20	Very uncomfortable	slightly warm	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	Room 190 next door(all windows) is like being in a greenhouse during warm days. It gets unbearable hot & stuffy during the day
21	Slightly comfortable	neutral	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
22	Very comfortable	neutral	sometimes	clearly acceptable	#N/A	The air flow is non exist in room 275 which is where I spend most of time this term. Very warm & stuffy
23	Slightly uncomfortable	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	

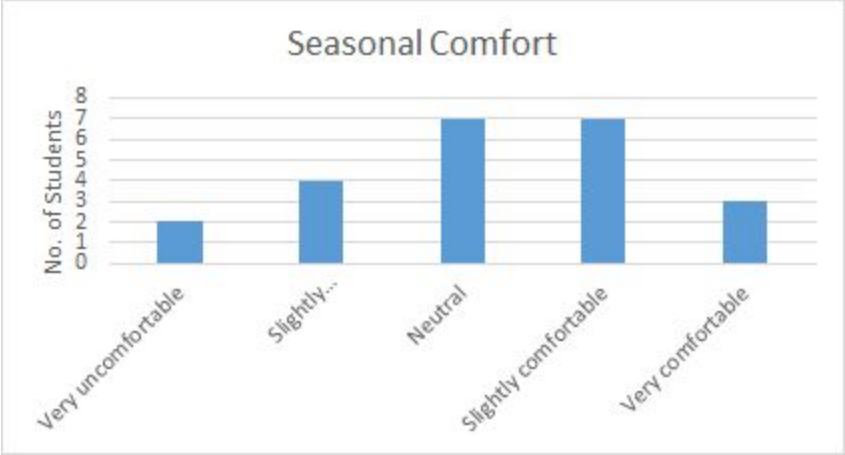


Figure C1. Survey 1 Question 2: Seasonal Comfort

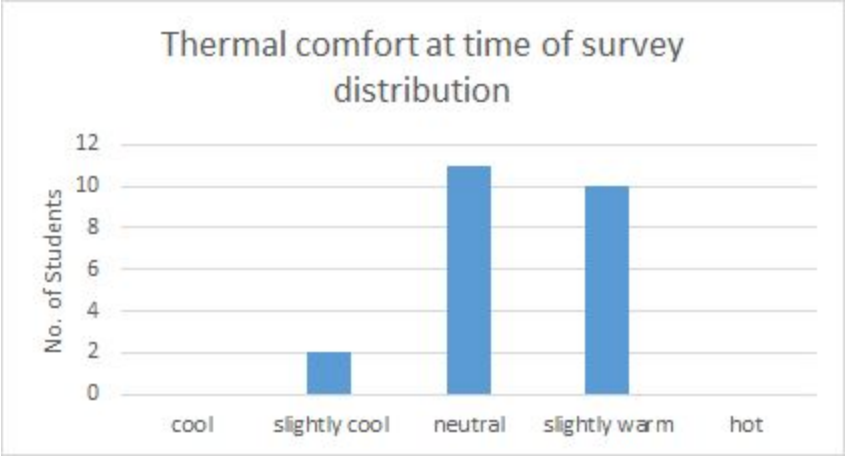


Figure C2. Survey 1 Question 3: Thermal comfort at time of survey distribution

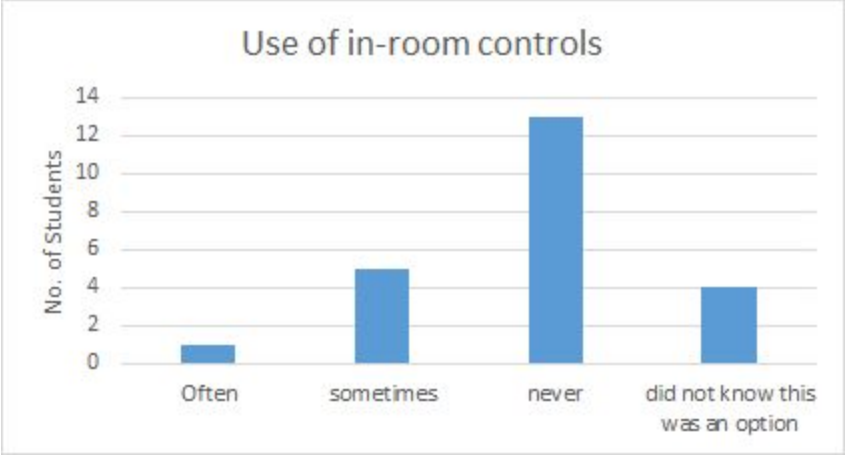


Figure C3. Survey 1 Question 4: Frequency of use of wall-mounted controls

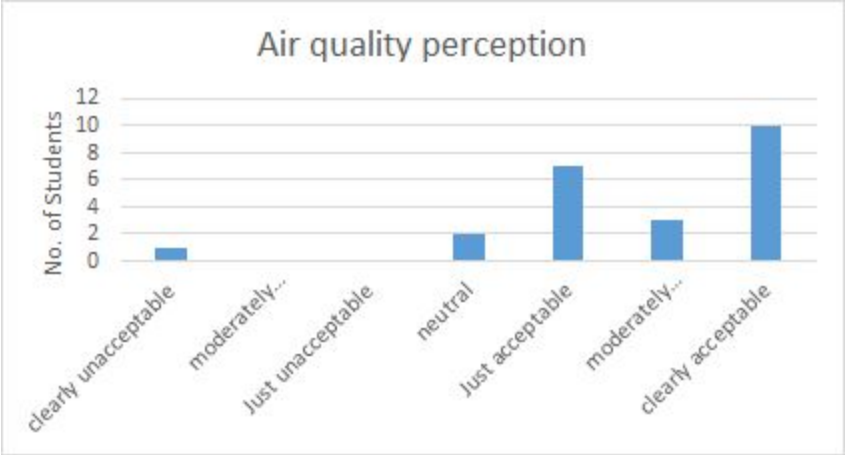


Figure C4. Survey 1 Question 5: Perceived air quality

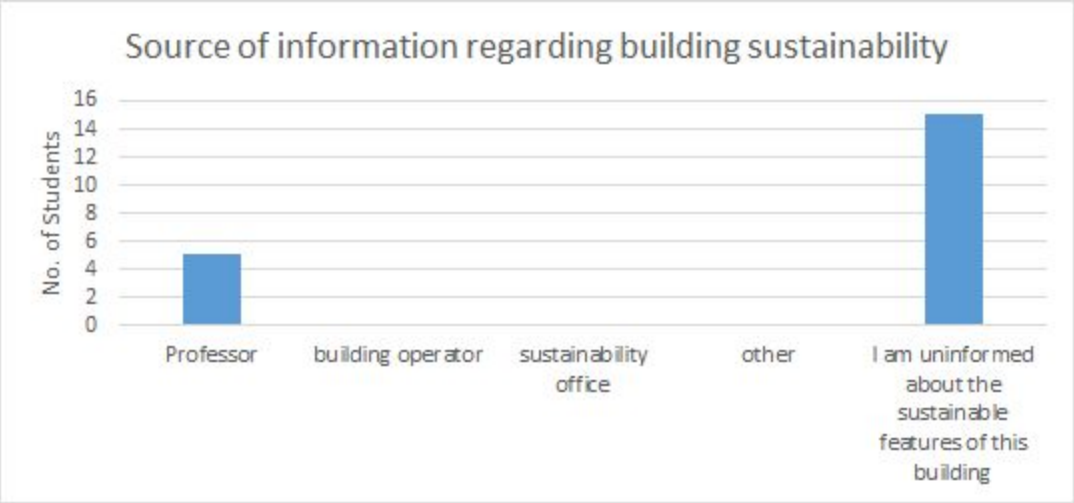


Figure C5. Survey 1 Question 6: Source of information regarding sustainable features of the KMC

Table C2. Survey 2: KMC 185, 5:30pm, Outdoor Temperature: 80.0, Indoor Temperature: 75.16

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Neutral	neutral	did not know this was an option	clearly acceptable	other	
2	Neutral	neutral	never	moderately acceptable	Professor	
3	Neutral	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
4	Neutral	neutral	never	Just acceptable	Professor	
5	Slightly comfortable	neutral	never	Just unacceptable	Professor	
6	Slightly comfortable	neutral	never	clearly acceptable	Professor	automatic windows really loud and should have a minimum timeframe between each opening/closing. They often open and then immediately close.
7	Slightly comfortable	slightly cool	never	Just acceptable	Professor	Window operation is loud and disrupts classroom

8	Slightly uncomfortable	slightly cool	never	clearly acceptable	Professor	
9	Slightly uncomfortable	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	
10	Slightly uncomfortable	neutral	never	clearly acceptable	I am uninformed about the sustainable features of this building	Ceiling fan kind of annoying. Windows can be distracting
11	Slightly uncomfortable	slightly cool	never	clearly acceptable	Professor	
12	Slightly uncomfortable	neutral	did not know this was an option	Just acceptable	other	distracting windows
13	Very comfortable	neutral	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
14	Very comfortable	neutral	never	clearly acceptable	I am uninformed about the sustainable features of this building	It's just hunky Dorry!
15	Very comfortable	slightly cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	
16	Very comfortable	slightly cool	sometimes	Just acceptable	Professor	I like the large windows for natural light

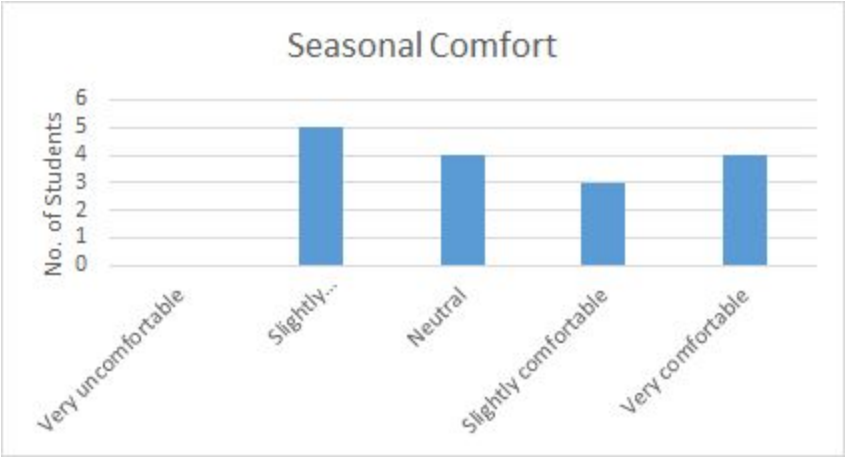


Figure C6. Survey 2 Question 2: Seasonal Comfort

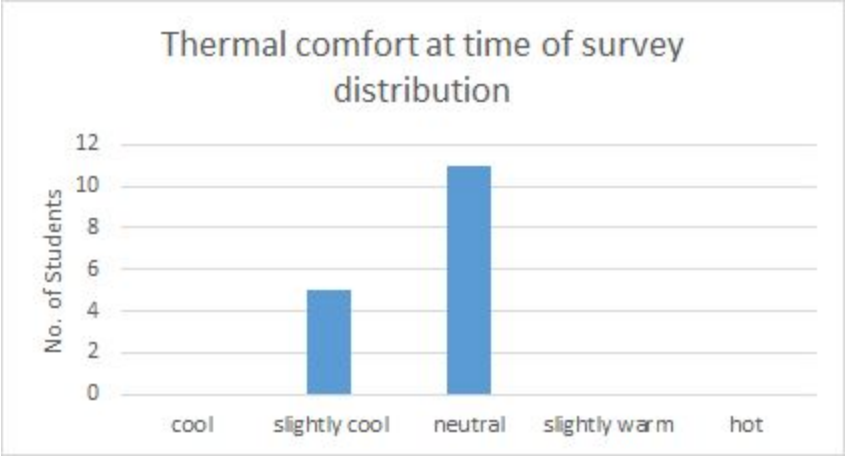


Figure C7. Survey 2 Question 3: Thermal comfort at time of survey distribution

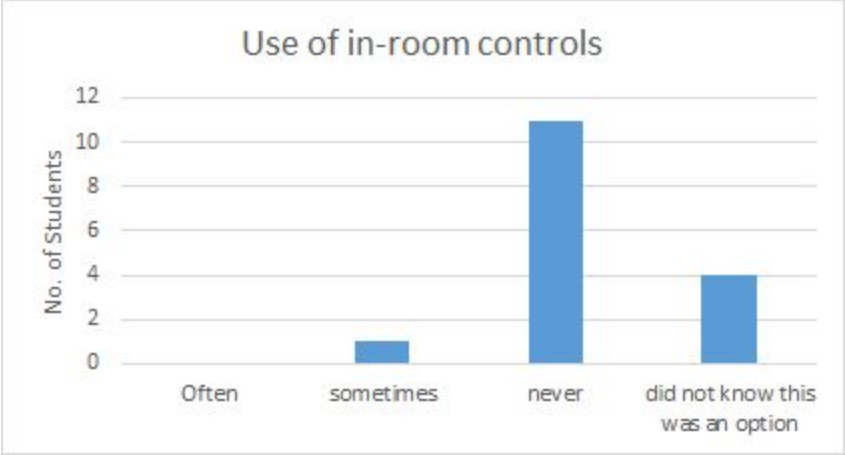


Figure C8. Survey 2 Question 4: Frequency of use of wall-mounted controls

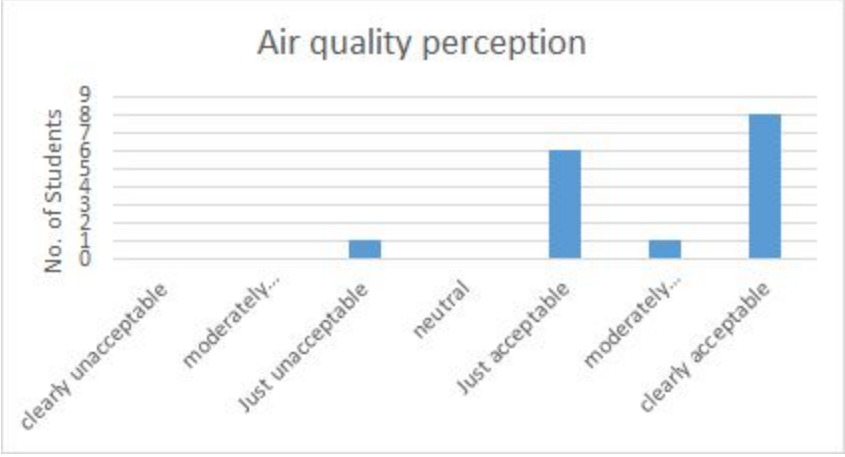


Figure C9. Survey 2 Question 5: Perceived air quality

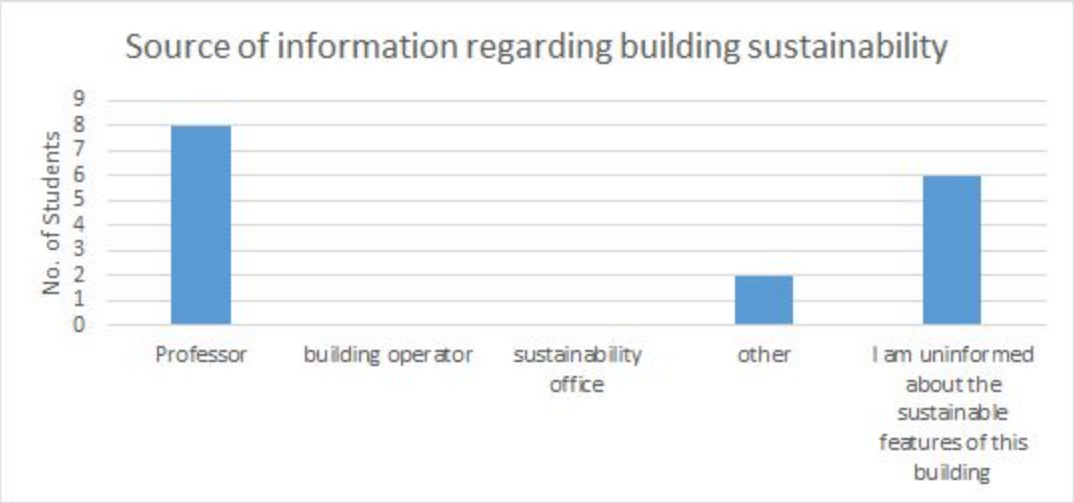


Figure C10. Survey 2 Question 6: Source of information regarding sustainable features of the KMC

Table C3. Survey 3: KMC 295, 11:30am, Outdoor Temperature: 76.0, Indoor Temperature: 73.18

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Neutral	cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	
2	Slightly comfortable	slightly cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	Sometimes it is too warm, today is nice
3	Slightly uncomfortable	neutral	never	moderately acceptable	I am uninformed about the sustainable features of this building	Noise when windows are open. Temperature is comfortable
4	Very comfortable	neutral	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
5	Neutral	neutral	did not know this was an option	Just acceptable	building operator	Everything is good!
6	Slightly uncomfortable	hot	never	Just unacceptable	I am uninformed about the sustainable features of this building	Request AC in this building
7	Very uncomfortable	slightly cool	never	Just unacceptable	sustainability office	

8	Very comfortable	neutral	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
9	Neutral	slightly cool	never	moderately acceptable	I am uninformed about the sustainable features of this building	Too many students wear sprays that stink up the entire classroom which is annoying. So maybe a system that sucks up air like at casinos with smoke would work. The water fountain has had flow issues all summer. Please fix it so it doesn't take up to 5 trys to fill one bottle.
10	Slightly comfortable	neutral	did not know this was an option	clearly acceptable	building operator	Good. Hope have bigger screen or more screen.
11	Neutral	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	Good
12	Very comfortable	slightly cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	
13	Slightly uncomfortable	slightly cool	never	clearly unacceptable	I am uninformed about the sustainable features of this building	
14	Very comfortable	slightly cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	The windows are kind of loud but other than that the classroom is great and the building overall is the best on campus.
15	Slightly uncomfortable	slightly warm	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this	When I get into the classroom around 10:25am it feels stuffy and

					building	too warm, but as the class progresses it gets cooler and more comfortable.
16	Neutral	slightly cool	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
17	Neutral	slightly warm	sometimes	moderately acceptable	I am uninformed about the sustainable features of this building	When I'm in the KMC I don't think about comfortability. I think that's more of a positive than a negative. I appreciate the use of fans rather than AC, it makes it easier to hear my professor/peers. The only thing that's uncomfortable is the interior color scheme. The lime-green walls and ceiling are distracting.
18	Neutral	slightly warm	never	moderately acceptable	I am uninformed about the sustainable features of this building	
19	Slightly comfortable	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	

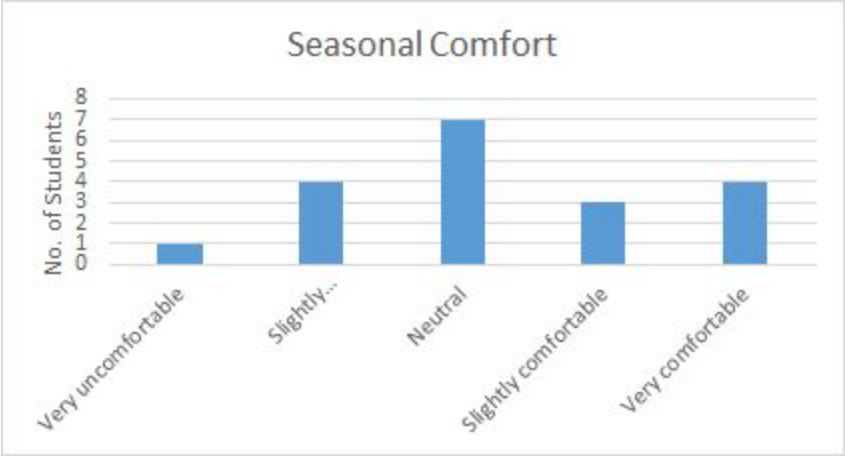


Figure C11. Survey 3 Question 2: Seasonal Comfort

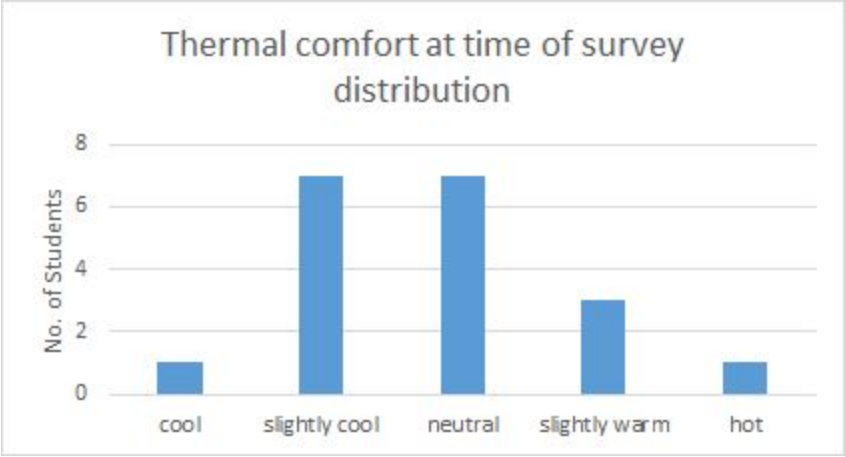


Figure C12. Survey 3 Question 3: Thermal comfort at time of survey distribution

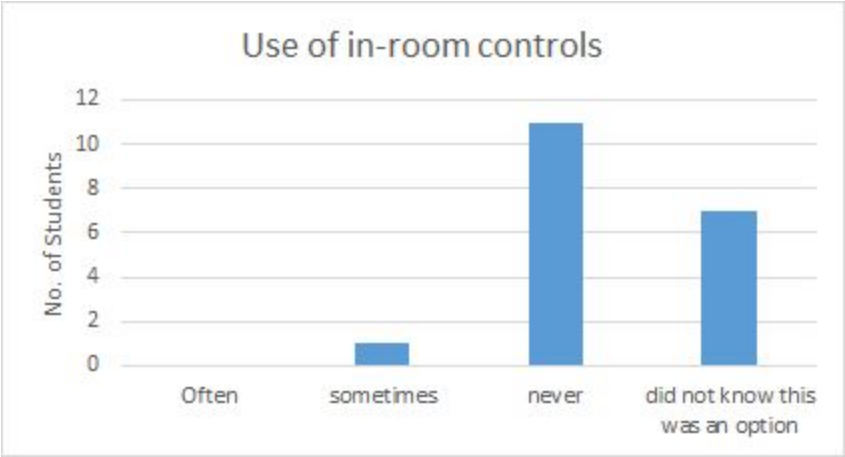


Figure C13. Survey 3 Question 4: Frequency of use of wall-mounted controls

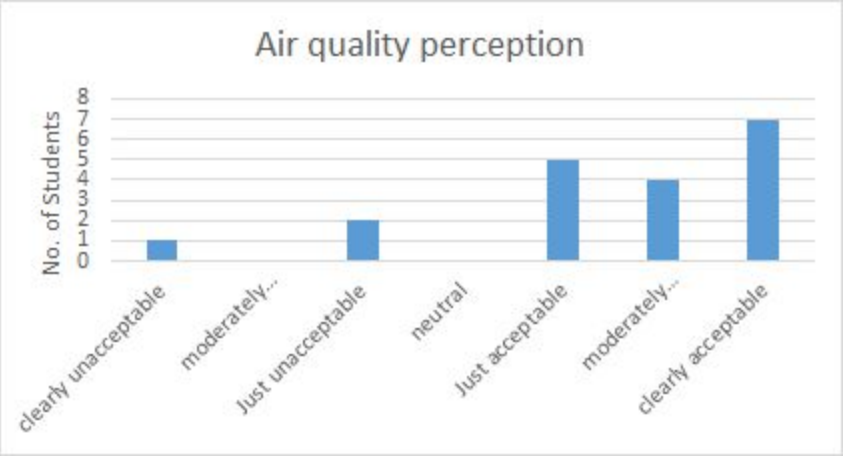


Figure C14. Survey 3 Question 5: Perceived air quality

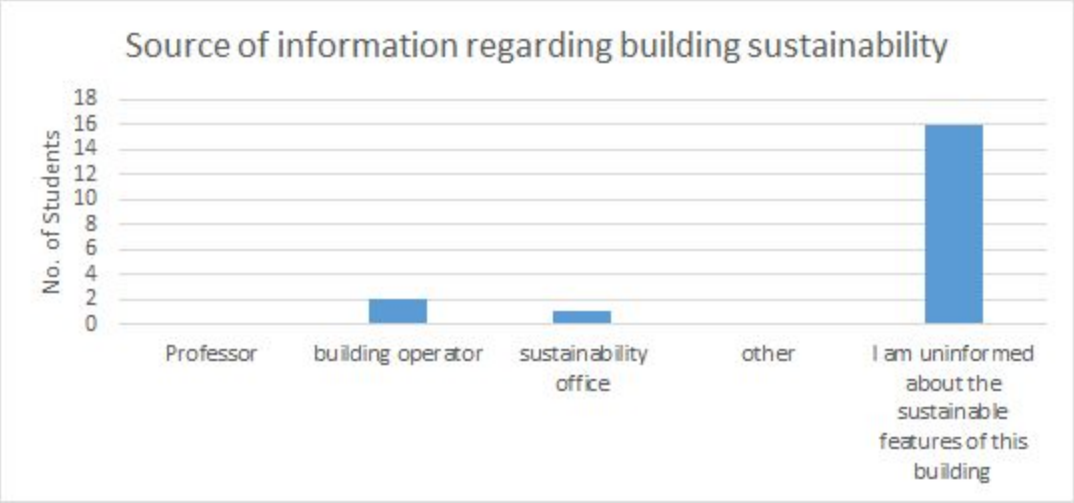


Figure C15. Survey 3 Question 6: Source of information regarding sustainable features of the KMC

Table C4. Survey 4: KMC 185, 12:50pm, Outdoor Temperature: 84.0, Indoor Temperature: 74.84

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Neutral	slightly cool	never	clearly acceptable	Professor	
2	Slightly uncomfortable	cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	rooms with auto windows and fans get too cold too fast. During a 90F summer day we travel lightly clothes so entering a computer lab or classroom that is 60F with the way

						the past few weeks have been is uncomfortable.
3	Neutral	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	The smell of the restaurant that is in the building is not cool
4	Very uncomfortable	hot	sometimes	clearly unacceptable		Should look after keeping students comfort instead of sustainability. I could care less about sustainability when I am sweating trying to learn.
5	Neutral	slightly cool	never	Just acceptable	I am uninformed about the sustainable features of this building	Thank you
6	Very comfortable	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
7	Neutral	cool	never	Just acceptable	I am uninformed about the sustainable features of this building	
8	Very comfortable	slightly cool	sometimes	clearly acceptable	Professor	Most of the time it's fine
9	Slightly uncomfortable	slightly warm	never	Just acceptable	I am uninformed about the sustainable features of this building	
10	Very uncomfortable	hot	Often	clearly unacceptable	I am uninformed about the sustainable features of this building	The downstairs classrooms are always stuffy/too hot. No air flow in bathrooms. Shame.
11	Slightly comfortable	neutral	never	Just unacceptable	I am uninformed about the sustainable features of this building	

12	Neutral	neutral	never	moderately acceptable	Professor	
13	Very comfortable	neutral	never	clearly acceptable	Professor	Surprisingly very comfortable and love the concept.
14	Neutral	slightly cool	never	clearly acceptable	Professor	

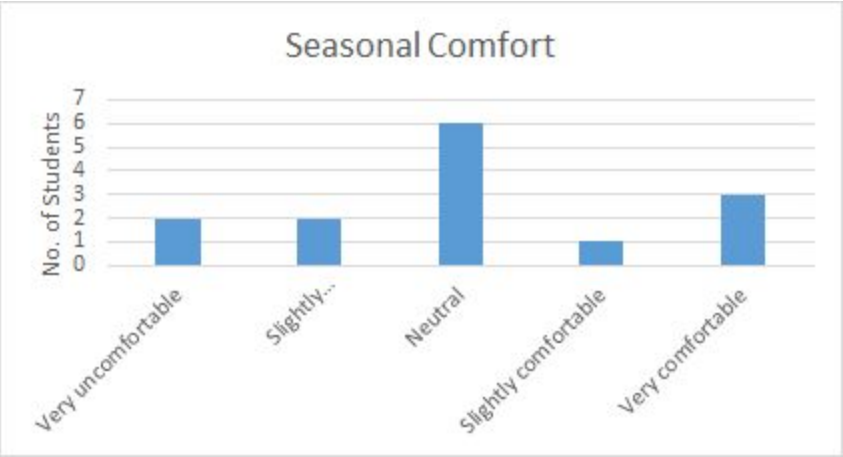


Figure C16. Survey 4 Question 2: Seasonal Comfort

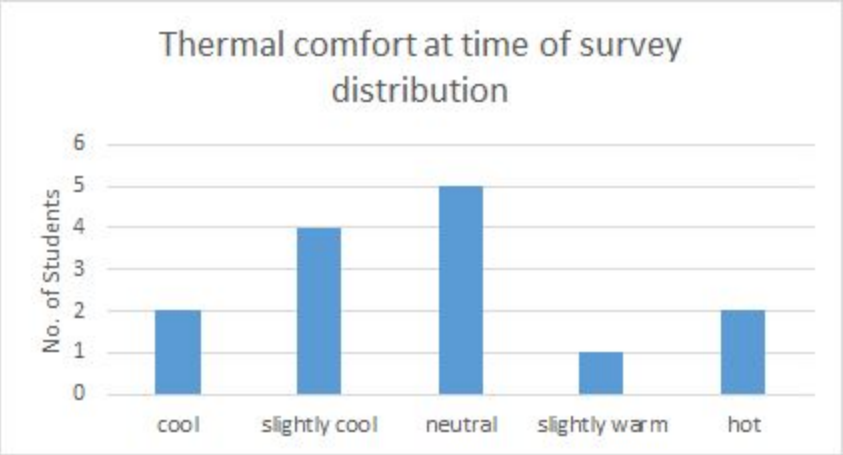


Figure C17. Survey 4 Question 3: Thermal comfort at time of survey distribution

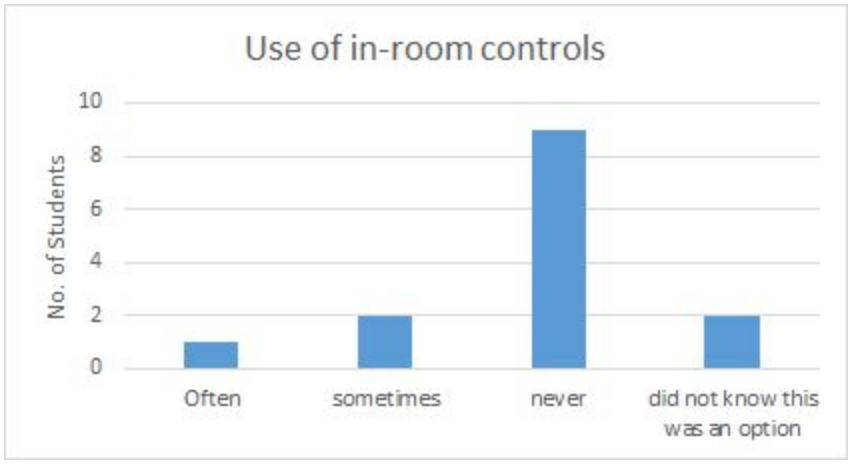


Figure C18. Survey 4 Question 4: Frequency of use of wall-mounted controls

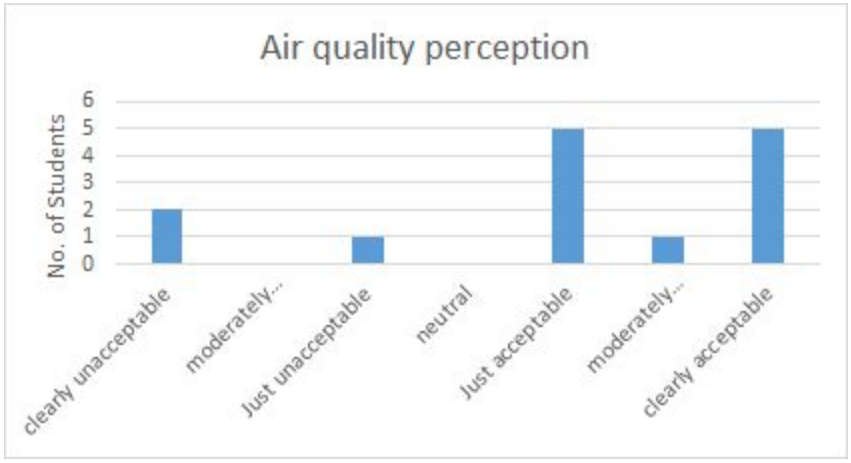


Figure C19. Survey 4 Question 5: Perceived air quality

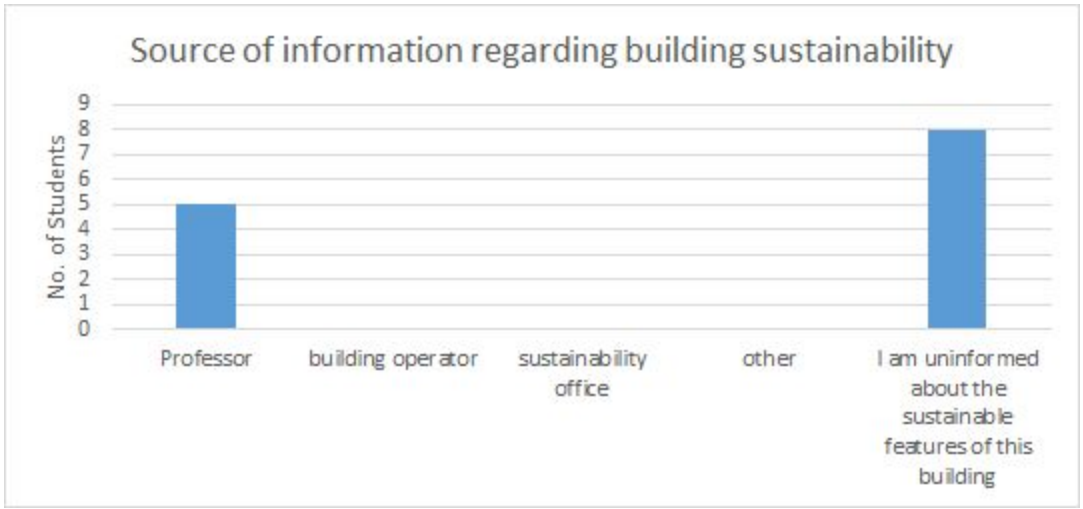


Figure C20. Survey 4 Question 6: Source of information regarding sustainable features of the KMC

Table C5. Survey 5: KMC 190, 10:30am, Outdoor Temperature: 77.0, Indoor Temperature: 77.2

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Slightly uncomfortable	slightly warm	sometimes	Just acceptable	Professor	
2	Slightly uncomfortable	slightly warm	sometimes	Just acceptable	Students, professor	Good comic relief
3	Very comfortable	neutral	sometimes	clearly acceptable	I am uninformed about the sustainable features of this building	I am very happy with it. Love hot weather.
4	Neutral	slightly warm	never	clearly acceptable	I am uninformed about the sustainable features of this building	I love the building, just sometimes gets stuffy
5	Neutral	slightly warm	Often	Just acceptable	I am uninformed about the sustainable features of this building	Noisy window. Too frequent opening and closing
6	Neutral	slightly warm	never	Just acceptable	Professor	Comfort is ok, just a little warm. The window noises are distracting though.
7	Slightly uncomfortable	neutral	sometimes	Just acceptable	I am uninformed about the sustainable features of this building	Too close to the street, so the street noise is annoying. The window is working too loud.
8	Very uncomfortable	slightly warm	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
9	Neutral	slightly warm	sometimes	Just acceptable	I am uninformed about the sustainable features of this building	Can we just have A/C please?
10	Slightly uncomfortable	slightly cool	Often	Just unacceptable	Professor	Do better
11	Slightly uncomfortable	hot	did not know this was an option	neutral	I am uninformed about the sustainable features of this	

					building	
12	Very uncomfortable	hot	sometimes	moderately unacceptable	Professor	Very uncomfortable to sit in class. Seems Skanska and architects did not consider this in the design.
13	Slightly comfortable	slightly warm	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
14	Slightly uncomfortable	slightly warm	sometimes	clearly acceptable	Professor	The classroom is usually really warm and the glass windows are very distracting (loud opening, people/activities outside) but I appreciate the green efforts of the design. :-)
15	Very uncomfortable	slightly warm	sometimes	Just unacceptable	I am uninformed about the sustainable features of this building	The room is also disrupted with windows and people constantly walking by and talking/shouting. Protests have gone by disrupting the class.
16	Neutral	neutral	did not know this was an option	moderately acceptable	I am uninformed about the sustainable features of this building	I'm usually comfortable, but occassionaly it gets a bit hot
17	Very uncomfortable	hot	sometimes	Just unacceptable	I am uninformed about the sustainable features of this building	It's hot all the time. The windows are distracting with the noise (closing and opening) and the noise of the people. Some classrooms not all fans work at once.

18	Slightly uncomfortable	slightly warm	did not know this was an option	Just unacceptable	I am uninformed about the sustainable features of this building	Automatic windows opening was always at the worst time possible and at ground level/street level it can get loud. Fans and window opening also doesn't always keep the room cool (I've come close to frying in the 190 room when the door wasn't open). Also the fishtank feel can make passerbys distracting. Finally, did anyone seriously read this?
19	Slightly uncomfortable	hot	sometimes	Just unacceptable	Professor, building operators	I hate how loud it gets.
20	Slightly uncomfortable	slightly warm	did not know this was an option	neutral	Professor	Windows are noisy and distracting. When manually changing windows (closing them) they don't stay changed but reset as programmed. Nobody knows how to work the fans.
21	Neutral	slightly warm	Often	clearly acceptable	building operator	Room 190 is probably the most visual distracting room. Maybe implement a shade to draw down so that bypassers do not distract the class. The room temp is adequate.

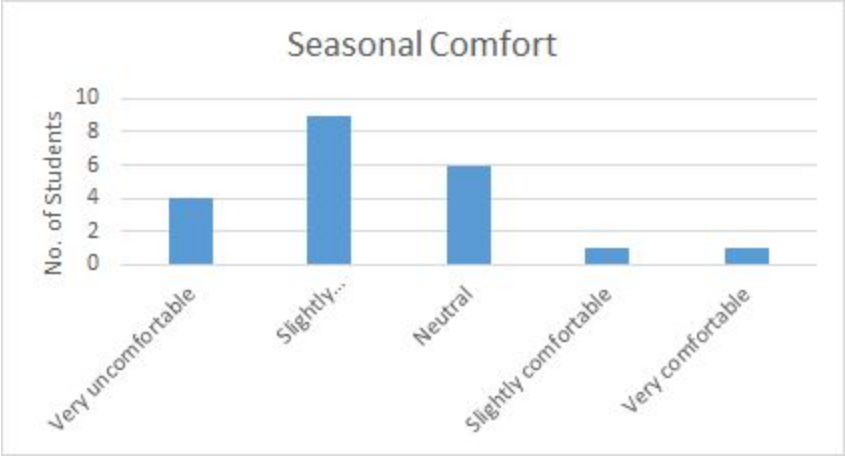


Figure C21. Survey 5 Question 2: Seasonal Comfort

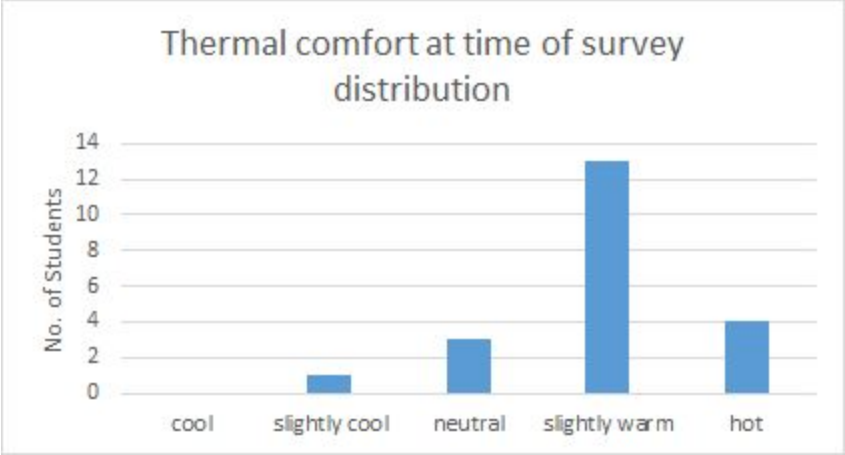


Figure C22. Survey 5 Question 3: Thermal comfort at time of survey distribution

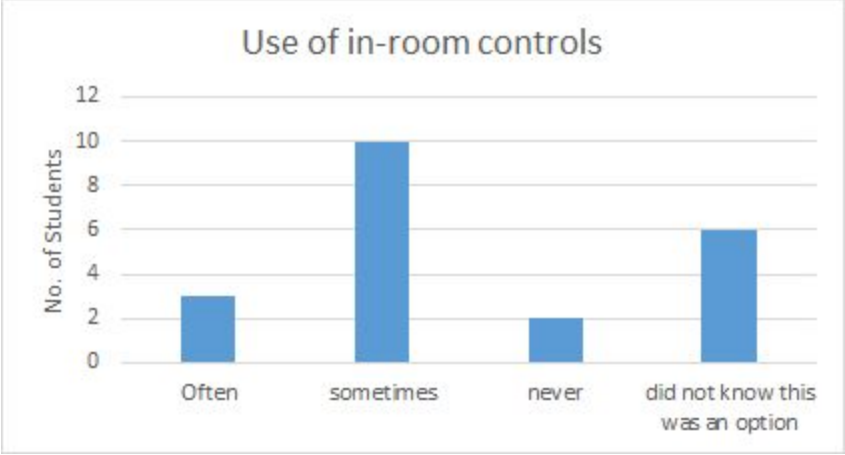


Figure C23. Survey 5 Question 4: Frequency of use of wall-mounted controls

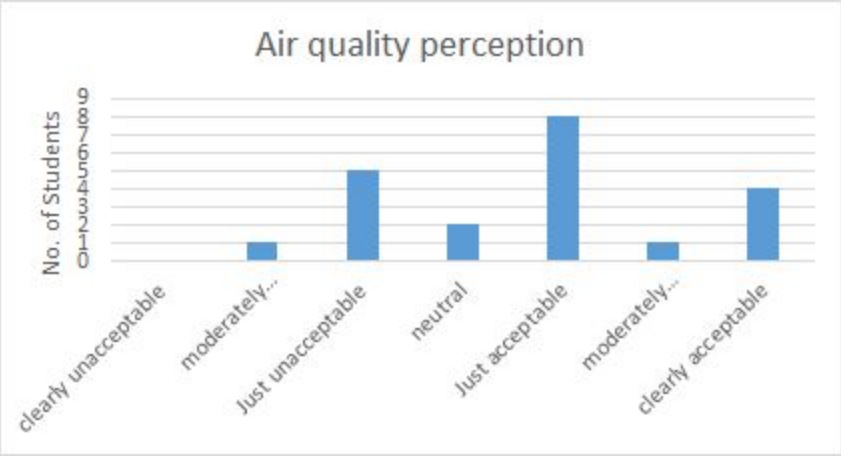


Figure C24. Survey 5 Question 5: Perceived air quality

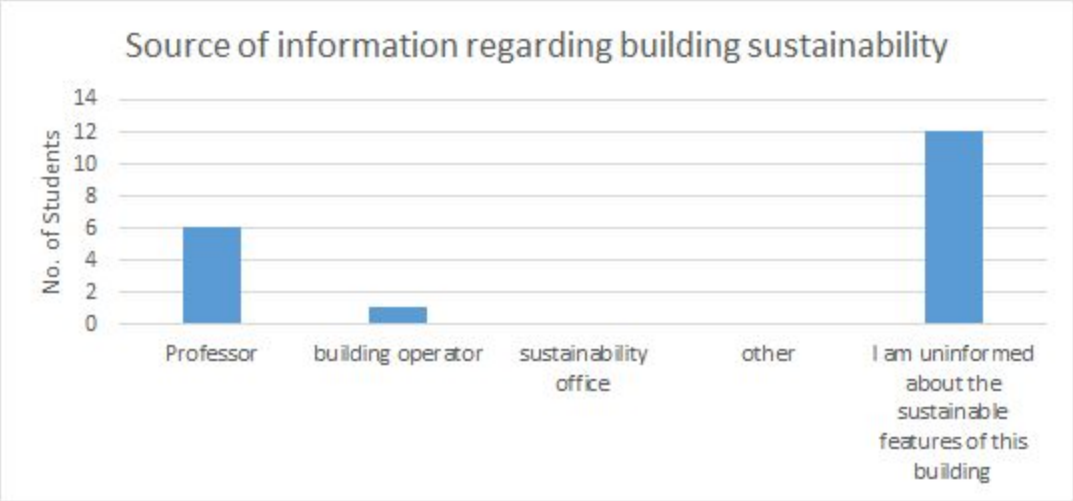


Figure C25. Survey 5 Question 6: Source of information regarding sustainable features of the KMC

Table C6. Survey 6: KMC 295, 10:30am, Outdoor Temperature: 77.0, Indoor Temperature: 71.2

Student	Seasonal	Comfort at Time of Survey	Control Use	Air Quality	Information Source	Comments
1	Neutral	neutral	sometimes	moderately acceptable	I am uninformed about the sustainable features of this building	
2	Neutral	slightly warm	never	Just acceptable	Professor	
3	Slightly comfortable	slightly cool	sometimes	clearly acceptable	Professor	Good job!
4	Slightly comfortable	neutral	did not know this was an option	moderately acceptable	I am uninformed about the sustainable features of this	

					building	
5	Very comfortable	neutral	never	clearly acceptable	other	Yay!
6	Neutral	neutral	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
7	Slightly comfortable	cool	never	Just unacceptable	I am uninformed about the sustainable features of this building	
8	Neutral	slightly cool	Often	clearly acceptable	I am uninformed about the sustainable features of this building	
9	Slightly comfortable	slightly cool	never	clearly acceptable	sustainability office	Feels good today
10	Very comfortable	neutral	never	Just unacceptable	other	
11	Very comfortable	slightly cool	never	clearly acceptable	sustainability office	
12	Slightly comfortable	neutral	did not know this was an option	moderately acceptable	I am uninformed about the sustainable features of this building	
13	Neutral	slightly cool	did not know this was an option	Just acceptable	I am uninformed about the sustainable features of this building	
14	Slightly uncomfortable	slightly warm	never	Just unacceptable	I am uninformed about the sustainable features of this building	
15	Slightly comfortable	slightly cool	never	clearly acceptable	I am uninformed about the sustainable features of this building	
16	Very comfortable	slightly warm	never	clearly acceptable	I am uninformed about the sustainable features of this building	Pleasant and quiet

17	Neutral	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	Thank You
18	Very comfortable	slightly cool	never	Just acceptable	I am uninformed about the sustainable features of this building	
19	Very comfortable	slightly warm	never	Just acceptable	I am uninformed about the sustainable features of this building	
20	Slightly comfortable	neutral	sometimes	neutral	Professor	
21	Neutral	slightly warm	never	moderately acceptable	Professor	
22	Neutral	slightly warm	sometimes	moderately acceptable	other	
23	Slightly comfortable	neutral	sometimes	Just acceptable	I am uninformed about the sustainable features of this building	Sometimes fans get too windy
24	Neutral	neutral	never	moderately acceptable		Good!
25	Neutral	neutral	never	Just acceptable	I am uninformed about the sustainable features of this building	
26	Slightly uncomfortable	slightly warm	did not know this was an option	Just unacceptable	I am uninformed about the sustainable features of this building	It's hot
27	Very comfortable	neutral	never	moderately acceptable	I am uninformed about the sustainable features of this building	Nice room, little weird walking by glass walls when entering room
28	Neutral	slightly cool	did not know this was an option	clearly acceptable	I am uninformed about the sustainable features of this building	
29	Slightly uncomfortable	slightly cool	never	Just acceptable	I am uninformed about the sustainable	

					features of this building	
30	Neutral	slightly warm	never	neutral		

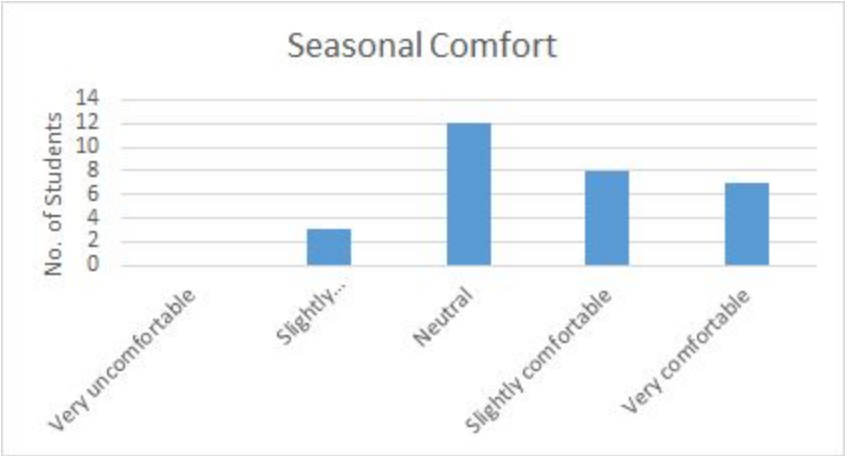


Figure C26. Survey 6 Question 2: Seasonal Comfort

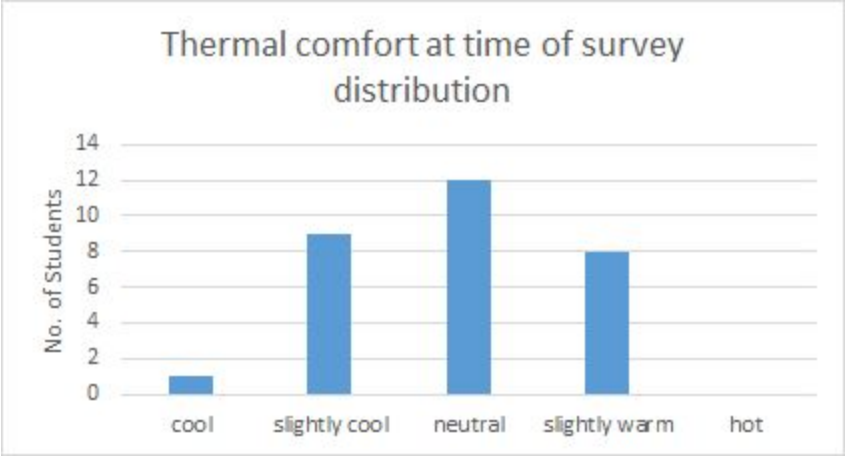


Figure C27. Survey 6 Question 3: Thermal comfort at time of survey distribution

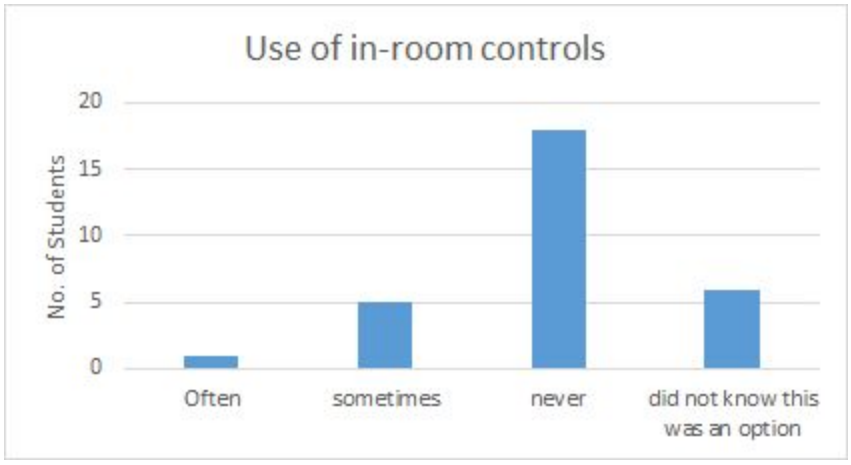


Figure C28. Survey 6 Question 4: Frequency of use of wall-mounted controls

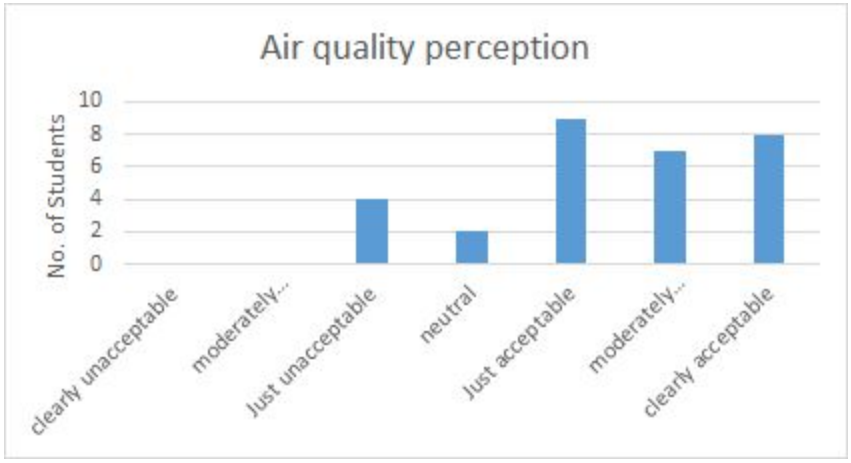


Figure C29. Survey 6 Question 5: Perceived air quality

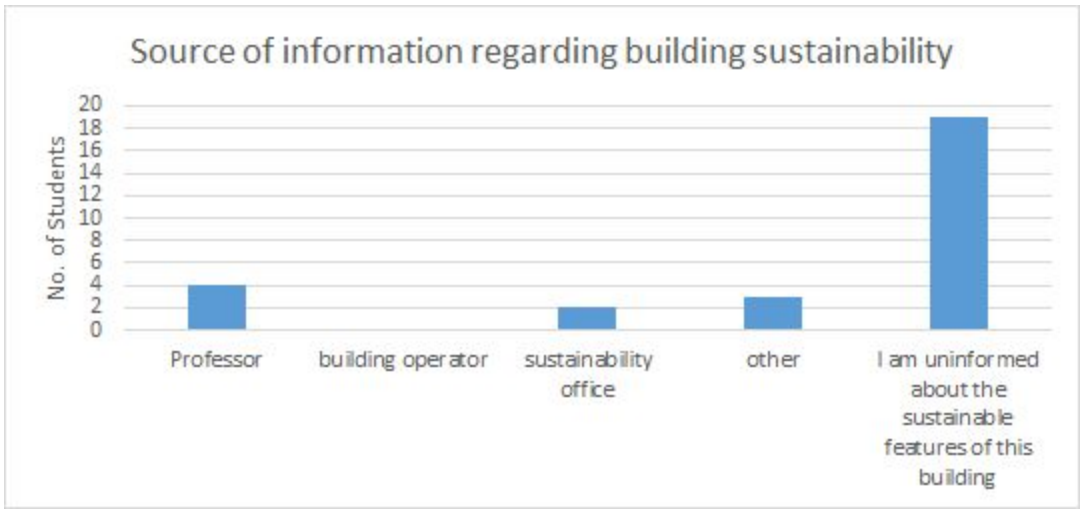


Figure C30. Survey 6 Question 6: Source of information regarding sustainable features of the KMC

Appendix D: Deployment of Temperature & Air Quality Instruments

Deployment of Temperature & Air Quality Instruments

KMC Research

The purpose of this deployment is to examine occupant satisfaction in Karl Miller Center(KMC), with the aim of comparing patterns to holding classrooms in the summer term.

1. Instruments

Type of Instrument	Departm ent	Number(EA)	Location(s)	Measurement(s)
Purple Airs	Elliott's Lab	15	Indoor 11 / Outdoor 4	Particulants
Tripods	CPC	2	Outdoor(3rd floor)	-
KMC weekly report(SIEMEN S Insight)	CPC	-	-	Temperature, CO2, RH
Kestrel Data Loggers	BUILT Lab	15	Indoor 11 / Outdoor 4	Temperature, RH
HOBO Weather Station	GBRL	1	Roof - Secured as the door to the roof is locked	Wind speed & direction

2. Deployment Locations

- Locations: Purple Airs and Kestrel Data Loggers will be located at Indoor and outdoor areas base on its characteristics; Daylight, a location of windows, and a number of frequent complaints.

Floor	Indoor	Outdoor
1st floor	Room 190	
2nd floor	Room 295, Room 255	
3rd floor	Room 385, Room 350, Room 390	Two spots on the patio (North and East)
4th floor	Room 480, Room 465, Room 495	
5tht floor	Room 580, Room 570	Two spots on the patio (South and West)
Loof		Weather station

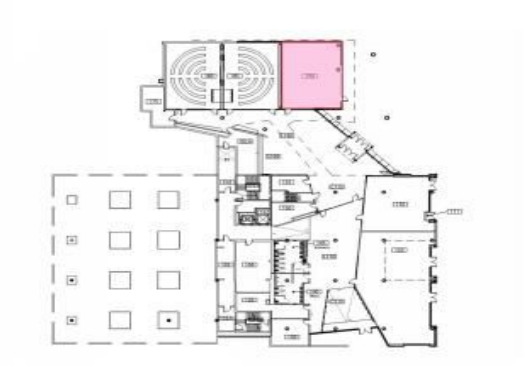
3. Picture Reference



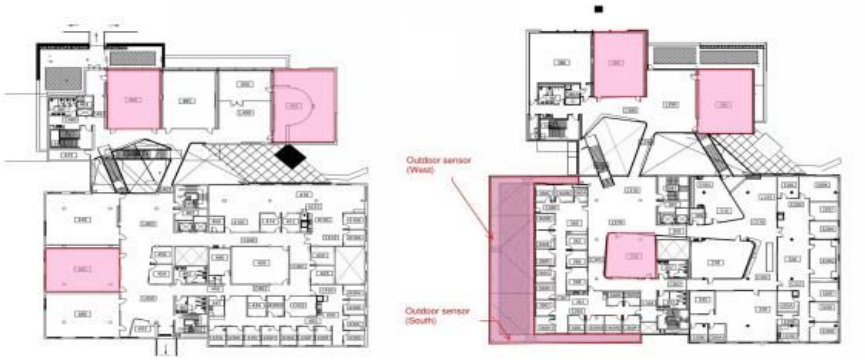


4. Floor Plans

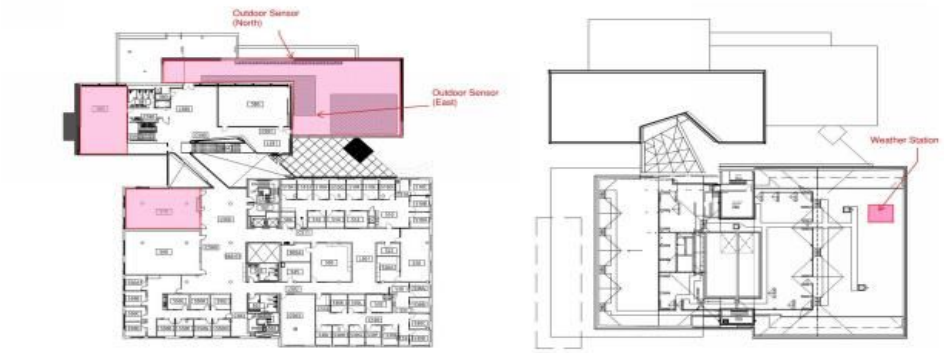
- 1st & 2nd floors

- 3rd & 4th floors



- 5th floor & roof

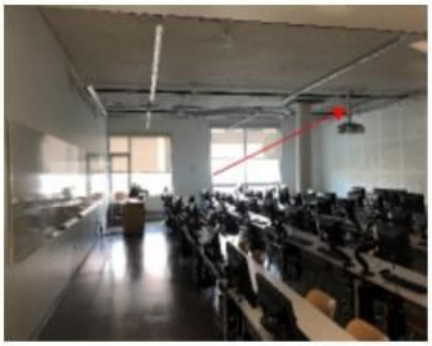


5. Deployment Placement details

Location	Purple Air (last 4 digits)	Kestrel (last 3 digits)	Placement	Picture reference
Room 190	EC FA BC B B1 6F	2209219	5.9m from West wall 7.2m from North windows 3.0m from floor	

Room 295	84 f3 EB 45 31 65	2209180	7.2m from West wall 6.4m from North windows 3.0m from floor	
Room 255	84 F3 EB 91 44 79	2209163	7.3m from West windows 6.1m from North wall 3.0m from floor	
Room 350	84 F3 EB 45 60 5C	2209239	3.7m from North wall 2.7m from West wall 3.4m from floor	
Room 390	68 C6 3A AE 59 42	2209182	6.1m from West wall 6.5m from North windows 3.0m from floor	

Room 385	84 F3 EB 91 44 3D	2209232	5.8m from West wall 6.3m from North windows 3.0m from floor	
Room 465	68 C6 3A 89 1D 78	2209257	5.0m from West wall 6.5m from North wall 3.0m from floor	
Room 480	5C CF 7F 5C 9E 2D	2209227	2.9m from West wall 6.0m from North windows 3.0m from floor	
Room 495	68 C6 38 8E 8D 7	2209061	6.8m from West wall 9.0m from North windows 3.0m from floor	

Room 560	60 1 94 4B 45 85	2209276	2.2m from West wall 5.2m from North windows 3.1m from floor	
Room 580	60 1 94 58 F0 D8	2209050	5.8m from West wall 5.8m from North windows 3.0m from floor	
3rd-floor Outdoor 1	60 1 94 58 D8 60 1 94 58 D8 D1	2209248		
3rd-floor Outdoor 2	84 F3 EB 91 8E 9	2209173		

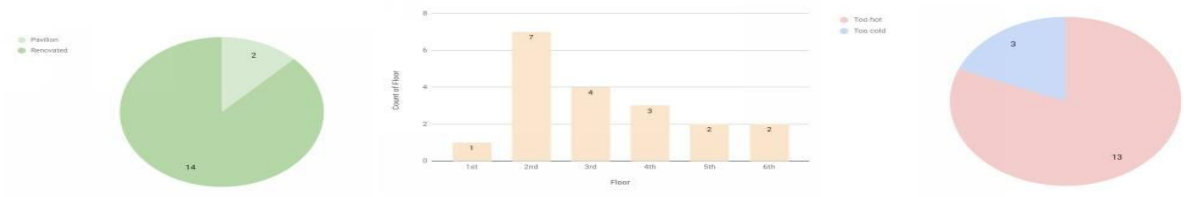
5th-floor Outdoor 1	84 F3 EB 91 44 5A	2209053	31.6m from West wall 0m from North wall 1.25m from floor	
5h-floor Outdoor 2	60 1 94 4B 45 79	2209235	28.6m from West wall 0m from South wall 1.1m from floor	
Roof Weather station	-	-	4.3m from West wall 4.8m from North wall 1.2m from floor	

Figure D1: Sensor deployment details & locations

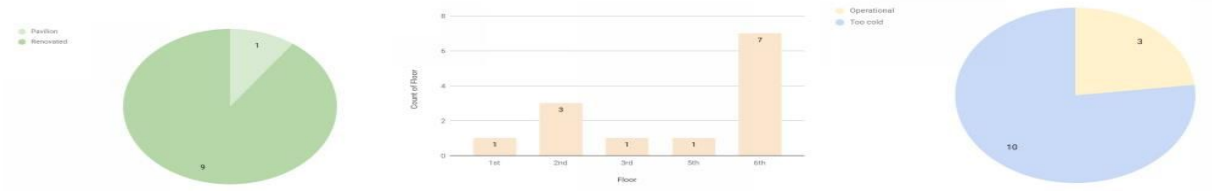
Appendix E: AIM Complaints

KMC AIM Complaints

- **2018 Summer (May 1st ~ Aug 15th)**



- **2019 Summer (May 1st ~ Aug 15th)**



- **2018 Summer Work order details**

Work Order	Date Created	Floor	Location	Type	Description
19-03146	8/1/2018	1st	Renovated	Too hot	KMC 150 -- room has been getting warmer than normal, the customer didn't indicate that any immediate action needed to be done they wanted this issue to be looking into for the future
18-27678	5/29/2018	2nd	Renovated	Too hot	Hello - I was wondering if you had an office fan for 230M Karl Miller School of Business. When the door is closed during appointments the room becomes extremely hot.
18-27851	5/31/2018	2nd	Renovated	Too hot	KMC 245 -- SECOND FLOOR -- Dept.: ryan depauw --It is almost 80 degrees in this room, according ot the thermostat! I can barely breathe, and it's too loud in the hallway to open a door. Could you fix the air in here? notified Jason
18-29371	6/21/2018	2nd	Renovated	Too hot	KMC -- Graduate School of Bussiness -- Hello Sarah requested AC to be on for KMC, I misinformed her about the AC in the building so I'm not sure what areas she needs the AC to be on in. Please follow up with her, she needs this done for this weekend
19-01871	7/16/2018	2nd	Renovated	Too hot	KMC 255 -- SECOND FLOOR -- Index: CMPG01 -- Dept.: Computer Science --The temperature in Karl Miller Center, room 255, is hoovering around 75 degrees. This is a 60 person classroom. Add 60 people in the room and their c...
19-02607	7/30/2018	2nd	Renovated	Too hot	KMC 210 -- SECOND FLOOR -- Index: SBAG10 -- It is about 10 degrees warmer in 210 than it is out in the hallway. Please help us correct airflow issues before it gets even hotter! -- contacted Jason Luce
19-04160	8/20/2018	2nd	Renovated	Too cold	KMC -- 255 room too cold -- Left VM for Jason
19-04657	8/29/2018	2nd	Renovated	Too hot	KMC 220 -- SECOND FLOOR -- Index: SBAG03 -- office 220 and 220c are hot/stuffy and it seems like the vents aren't working -- called Jason Luce

19-01969	7/17/2018	3rd	Renovated	Too hot	KMC 320D -- THIRD FLOOR -- Office is 75 degrees- too hot to work in. Can something be done for this asap? - notified Julio
19-02495	7/26/2018	3rd	Renovated	Too hot	KMC 320D -- THIRD FLOOR -- This office is too warm. It is at 74 degrees. Can someone please turn the temp down ASAP before it gets hotter outside?
19-02608	7/30/2018	3rd	Renovated	Too hot	KMC 320G -- THIRD FLOOR -- Dept.: School of Business --Please come turn down the thermostat in the Dean's Office. It is 78 degrees and climbing. Thanks! -- contacted Jason Luce
18-25974	5/4/2018	3rd	Pavilion	Too hot	KMC 380 -- THIRD FLOOR -- The ceiling fan nearest the instructor podium in classroom 380 clicks when running and is distracting students. Fridays are a good time because there are no classes scheduled. The room is heavily used during other days.
18-26902	5/17/2018	4th	Renovated	Too hot	KMC -- FOURTH FLOOR -- The KMC is too hot! I sweat through all of my clothes in every class, every single day. Instructors and students have also complained about this. I have to change my clothes every time I come home f...
18-29493	6/25/2018	4th	Renovated	Too hot	Room 460 in KMC was too hot. Jason Luce was notified, please add phase for systems
18-29575	6/25/2018	4th	Renovated	Too hot	ONE CALL: 6/23/18 Sarah Schroeder reported that room 460 in KMC was too hot. Jason Luce was notified, please add phase for systems
18-27861	5/31/2018	5th	Renovated	Too hot	KMC 560 -- FIFTH FLOOR -- it is currently 78 degrees in this room although it feels hotter, even though the windows are open. Please turn on the AC or bring a fan as soon as possible notified Jason
18-28741	6/12/2018	5th	Renovated	Too cold	KMC 570 -- FIFTH FLOOR -- The lab is very cold and some users are requesting to have the ac turned off.
18-26330	5/8/2018	6th	Pavilion	Too hot	KMC 580 -- FIFTH FLOOR -- Faculty member reported the ceiling fans are not working and students are complaining the room is too hot.

18-29098	6/18/2018	6th	Renovated	Too cold	KMC 605 -- SIXTH FLOOR -- Index: ISP110 -- Room is usually very cold. Please come and check it out, and perhaps reset the thermostat. Thank you!

- **2019 Summer Work order details**

Work Order	Date Created	Location	Floor	Type	Description
19-26142	6/12/2019	Pavilion	1st	Operational	KMC 190 -- FIRST FLOOR -- The fan closest to the door won't start.
19-26292	6/14/2019	Renovated	2nd	Too cold	KMC KMC 255 -- SECOND FLOOR -- The classroom is 64 degrees and the class is very cold for their final exam.
20-02846	7/30/2019	Pavilion	2nd	Operational	KMC room 285 ceiling fans not working Jason luce
20-03647	8/8/2019	Pavilion	2nd	Operational	KMC--Assistance turning on fan (contacted Mike McBride)
19-23796	5/16/2019	Renovated	3rd	Too cold	KMC 320D -- THIRD FLOOR -- Office is too cold, please turn temperature up.
20-02121	7/16/2019	Renovated	5th	Too cold	KMC 570 OIT Lab -- FIFTH FLOOR -- The AC in the room is too cold. Can you adjust it down a bit please? Thank you
19-23600	5/14/2019	Renovated	6th	Too cold	KMC 610A -- SIXTH FLOOR -- Dept.: International Affairs --Please allow me to turn OFF the A/C in my office.
19-23797	5/16/2019	Renovated	6th	Too cold	KMC 630B -- Room is too cold -- Notified Jason
19-24390	5/22/2019	Renovated	6th	Too cold	KMC 602 - Room is too cold. This is a reoccurring issue with this room and Karin is requesting if someone could investigate what is going on there. Notified Julio
19-25988	6/10/2019	Renovated	6th	Too cold	KMC 610A -- want to close the AC vent in my office. How can we make that happen? It's cold in KMC 610A and I have two sweaters on already.

19-27037	6/26/2019	Renovated	6th	Too cold	KMC -- 605 -- Cold room
20-00055	7/1/2019	Renovated	6th	Too cold	KMC -- 605 -- Cold room. Left VMs for Jason Luce & Dave Hurley.
20-02825	7/29/2019	Renovated	6th	Too cold	KMC 610A -- Please turn OFF the vent in this room (610A, KMC) cuz it's so freaking cold! Yes, I'm already wearing a sweater.

Figure E1: Complaints on summer 2018 vs. 2019