



**Indoor Environmental Quality + Classroom Environment
Heikkila Chemistry and Advanced Material Science Building
University of Minnesota, Duluth**

**June 2023, Minneapolis, MN
Sustainable Post-Occupancy Evaluation Survey (SPOES)
B3 Guidelines**

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1.0 Overview

The purpose of this report is to examine the connection between sustainable design criteria used in the design and construction of the Heikkila Chemistry and Advanced Materials Science Building (HCAMS) and occupants' satisfaction with their classroom environments located in this building. The HCAMS facility was designed using the 2009 B3 Guidelines (formerly known as the Minnesota Sustainable Building Guidelines or MSBG), which were in effect at the time that the new facility was completed for occupancy in August 2019. The B3 Guidelines track specific state funded B3 buildings as a means of demonstrating real outcomes aimed at the conservation of energy resources, creation and maintenance of healthy environments, and occupants' satisfaction with their environments. The Sustainable Post-Occupancy Evaluation Survey (SPOES) was developed to assess human outcomes in workplace, classroom, and residence hall settings in compliance with the B3 Guidelines project tracking requirements. This is a report of occupants' (hereafter called students) responses nearly 42 months post-occupancy, including two years of vacancy during the COVID-19 pandemic. The survey was conducted in April 2023.

This SPOES report focuses on students' satisfaction with the physical environment as related to 23 indoor environmental quality (IEQ) criteria such as lighting, thermal, and acoustic conditions in their primary classrooms. Students' satisfaction with the facility (site, building, and interior) and the effect of the facility's physical environment on their perceptions of their academic performance and health also are included. Finally, a brief look at students' commuting and physical activities within the building are reported. The report provides descriptive information about students' perceptions of the IEQ of their classroom environments. In addition, this information serves the broader development of knowledge regarding the influence of IEQ on students.

2.0 Method

SPOES consists of a self-administered, Internet-based, questionnaire submitted to and completed by students. The SPOES questionnaire has been tested for **validity** (measures what it is intended to measure) and **reliability** (repeatability or replicability of findings). Students rate their level of satisfaction on a **Likert-type scale** (measurement scale) from 1 (very dissatisfied) to 7 (very satisfied) with the IEQ of the facility and their primary classrooms. They also rate the influence of their physical environment on their perception of their academic performance and health on a scale from 1 (hindered) to 7 (enhanced).

The report provides a descriptive summary of the results stated as a **mean** (average of all responses), **standard deviations** (SD) (how different scores are from each other and the mean), and **number of responses** (N) for each question analyzed. The mean for a 7-point scale is 4.00. Lower or higher means reflect stronger tendencies towards dissatisfaction/satisfaction and hindered/enhanced. Means that are close to the center of the scale (4) are considered to be neither dissatisfied/hindered or satisfied/enhanced.

When interpreting **mean** responses, the following labels were used:

- 1.00 - 3.50 dissatisfied (or hindered)
- 3.51 - 4.50 neither dissatisfied (or hindered) nor satisfied (or hindered)
- 4.51 - 7.00 satisfied (or enhanced)

An IEQ Score is also calculated for students' satisfaction with IEQ in their primary classrooms. This is a statistical combination of category-level IEQ scores, which results in a single IEQ score for all respondents and is reported in an IEQ Scorecard.

2.1 Description of the Questionnaire

Students first rate their level of satisfaction with the facility (site, building, and interior) and the influence of their physical environment on their perception of their academic performance and health. Then they respond to questions about their satisfaction with their primary classrooms in relation to IEQ criteria from the B3 Guidelines. Additionally, students' physical activities and commuting practices are investigated.

In the SPOES questionnaire, the 23 IEQ criteria listed below are evaluated. There are two levels of criteria, categories and attributes. As shown in the list, the 'overall' criteria are boldfaced and called 'categories' or 'category level' criteria. A category is broader or more general such as Overall View Conditions or Overall Indoor Air Quality. Some categories have 'attributes' or 'attribute level' criteria and provide greater detail about the category. For example, Overall Thermal Conditions is a category level question, and there are four attribute level questions related to thermal conditions such as adjustability, air velocity (draft), humidity, and temperature. Overall Acoustic Conditions is a category with an attribute of students' ability to hear desired sounds. There are 11 category-level and 12 attribute level questions. Means are calculated and reported for all category and attribute-level criteria.

An IEQ Satisfaction Score is also calculated for students' satisfaction with IEQ in their primary classrooms. This is a statistical combination of the 11 category-level criteria only and results in a single, mean IEQ Satisfaction Score for students' satisfaction with the physical conditions of their primary classrooms. Attribute-level criteria are not included in the IEQ Score because unequal weight would be given to criteria that have both category and attribute-level questions.

In the following list, **category (boldface)** criteria are listed in alphabetical order. If a category has attributes, they are listed with the category.

Overall Acoustic Quality

- Ability to hear desired sounds (lecture, video, discussions, etc.)

Overall Appearance (aesthetics)

Overall Cleaning and Maintenance

Overall Daylighting Conditions

- Ability to adjust daylighting
- Amount of daylighting

Overall Electric Lighting Conditions

- Ability to adjust electric lighting
- Amount of electric lighting

Overall Furnishings

- Ability to adjust furnishings

- Function of furnishings

Overall Indoor Air Quality

Overall Technology (presentation, laptop support, etc.)

- Access to electric outlets

Overall Thermal Conditions

- Ability to adjust thermal conditions
- Air velocity (drafty/stagnant)
- Humidity (dry or moist)
- Temperature (hot or cold)

Overall Vibration and Movement

Overall View Conditions (ability to see instructor, screens, etc.)

2.2 Limitations

Students' participation is voluntary, and responses are self-reported. As is true with all survey research, the responses indicate students' perceptions. There were no physical measurements, e.g., temperature, humidity, or lighting levels of the environment taken. The classrooms are shown as a congregate measure, not analyzed individually. This study is limited to students' perceptions.

3.0 Sample Description

3.1 Description of Building

The HCAMS facility is located at 1038 University Drive in Duluth, MN. HCAMS is a 3 story, 56,000ft² building. It is comprised of 3 floors above grade. Classroom and lab spaces are distributed throughout the facility. In addition, there are lounge areas; public (and circulation) space; support space and restrooms; and mechanical/electrical, and custodial space HCAMS is the principal classroom building for the Department of Chemistry and Biochemistry and houses the Advanced Materials Center. Only the overall facility and learning spaces noted above were included in this study.



Figure 1. HCAMS (Photo courtesy of BWBR)

3.2 Project Team

The relevant project team members to the SPOES process for HCAMS was comprised of the owner, design team, and commissioning agent. They are identified below, relative to their capacity and involvement.

Owner	University of Minnesota
Architect	BWBR
Mechanical and Electrical Engineer	Dunham Associates
Interior Designer	BWBR
Landscape Architect	Damon Farber Associates
Commissioning Agent	University of Minnesota – Duluth

3.3 Description of Respondents

The HCAMS facility had 119 students with classes in the constructed facility during the spring semester administration of the survey. The response rate to the questionnaire was approximately 13%. Of those responding, 55% were male, and 45% were female. The mean age of respondents was 24 years; the range was 19 to 55 years.

Students responded that relative to their primary laboratory or classroom environment, 18% spend 1-2 hours per week in their primary laboratory or classroom environment, 27% spend 3-4 hours, 55% spend 5+ hours, and no respondents spend 40 hours or more per week in their primary classroom or laboratory environment. This indicates how much they are exposed to the laboratories'/classrooms' IEQ.

4.0 Findings and Discussion

4.1 HCAMS Facility (Site, Building, and Interior): Overall Satisfaction, Learning Experience, and Health

Students responded to questions concerning the HCAMS facility (site, building, and interior) and their overall satisfaction with the facility, overall perceptions of their learning experience in relation to the facility, and their overall perception of their health in relation to the facility. Table 1 shows the means and standard deviations of their responses as well as how the responses are interpreted. Figure 2 is a graph that shows the mean for each question with a blue mark. The standard deviation is represented by a green/red, vertical bar with green representing satisfied (or enhanced) and red representing dissatisfaction (or hindered). Gray represents the 'neither/nor' range of responses. In cases where there were no dissatisfied responses, the bar will be all grey and green. This graph is simply a visual image of the findings from Table 1.

Overall	Mean	SD	N	Interpretation
Satisfaction	6.50	0.65	12	Satisfied
Learning Experience	5.33	0.85	12	Enhanced
Health	4.75	0.92	12	Enhanced

Table 1. HCAMS facility - overall satisfaction, learning experience, and health

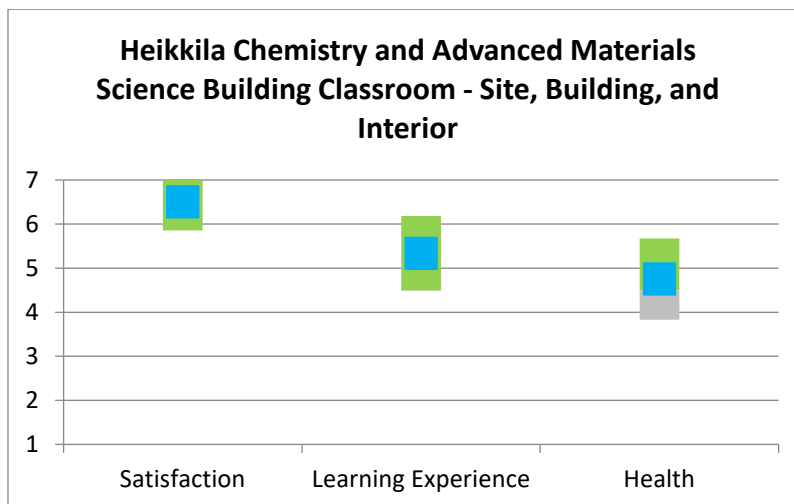


Figure 2. HCAMS facility - overall satisfaction, learning experience, and health

Results indicate that students were **satisfied (M = 6.50)** with the HCAMS facility (building, site, and interior) and reported that their overall learning experience was **enhanced (M = 5.33)** by the facility. Students reported that their overall health was **enhanced (M = 4.75)** by the facility.

4.2 Primary Classroom: Overall Satisfaction, Learning Experience, and Health

Students responded to questions concerning their overall satisfaction and overall perceptions of their learning experience and health as related to their primary laboratory/classroom. Table 2 shows the means and standard deviations of their responses as well as how the responses are interpreted. Figure 3 is a visual image of the findings from Table 2.

Overall	Mean	SD	N	Interpretation
Satisfaction	6.17	0.55	12	Satisfied
Learning Experience	5.83	0.55	12	Enhanced
Health	4.75	1.09	12	Enhanced

Table 2. HCAMS primary classroom/laboratory – overall satisfaction, learning experience, and health

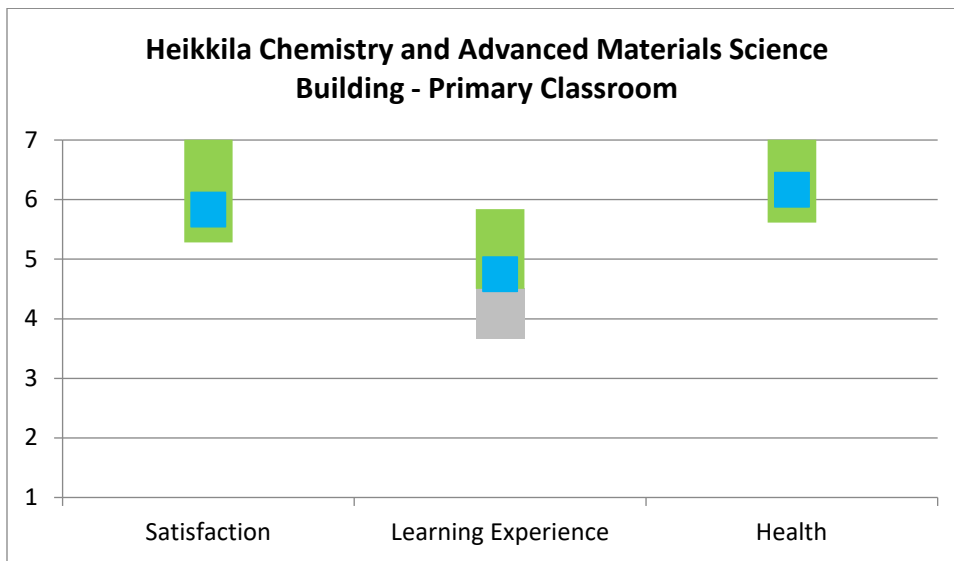


Figure 3. HCAMS primary classroom/laboratory - overall satisfaction, learning experience, and health

Results indicate that students were **satisfied (M = 6.17)** with their primary classroom, their overall learning experience was **enhanced (M = 5.83)** by their primary classroom, and their overall health was **enhanced (M = 4.75)** by their primary classroom.

4.3 Primary Classroom/Laboratory: Satisfaction with Indoor Environmental Quality (IEQ)

Students responded to questions concerning their satisfaction with IEQ criteria (thermal conditions, indoor air quality, acoustic conditions, etc.) related to their primary classroom. Table 3 shows the means and standard deviations of their responses in order from highest to lowest mean, as well as how the responses are interpreted. It must be noted that all responses, regardless of the classroom, were combined so these are composite means of all classrooms in HCAMS. Figure 4 is a visual image of the findings in Table 3.

#	IEQ Criteria (1-26) (Category level criteria are bold face)	Mean	SD	N	Interpretation (D = Dissatisfied) (S = Satisfied)
1	Amount of daylighting	6.42	0.76	12	Satisfied
2	Overall daylighting	6.33	0.85	12	Satisfied
3	Overall cleaning and maintenance	6.33	0.85	12	Satisfied
4	Overall appearance (aesthetics)	6.08	0.86	12	Satisfied
5	Amount of electric light	6.00	0.91	12	Satisfied
6	Adjustability of daylighting	6.00	1.00	12	Satisfied
7	Overall vibration and movement	6.00	1.22	12	Satisfied
8	Overall electric lighting conditions	5.83	0.90	12	Satisfied
9	Overall view conditions	5.83	1.14	12	Satisfied
10	Ability to hear desired sounds	5.75	0.83	12	Satisfied
11	Ability to adjust electric lighting	5.75	1.23	12	Satisfied
12	Access to electric outlets	5.75	0.72	12	Satisfied
13	Overall indoor air quality	5.50	1.19	12	Satisfied
14	Overall technology conditions	5.50	1.04	12	Satisfied
15	Humidity (dry or moist)	5.33	0.75	12	Satisfied
16	Air velocity (drafty or stagnant)	5.25	0.92	12	Satisfied
17	Overall acoustic quality	5.25	1.01	12	Satisfied
18	Function of furnishings	5.17	0.99	12	Satisfied
19	Overall furnishings	4.75	1.16	12	Satisfied
20	Adjustability of furnishings	4.67	1.25	12	Satisfied
21	Overall thermal conditions	4.50	1.38	12	Satisfied
22	Adjustability of thermal conditions	4.08	1.55	12	Neither S nor D
23	Temperature (hot or cold)	3.92	1.38	12	Neither S nor D

Table 3. HCAMS primary classroom/laboratory - satisfaction with IEQ criteria

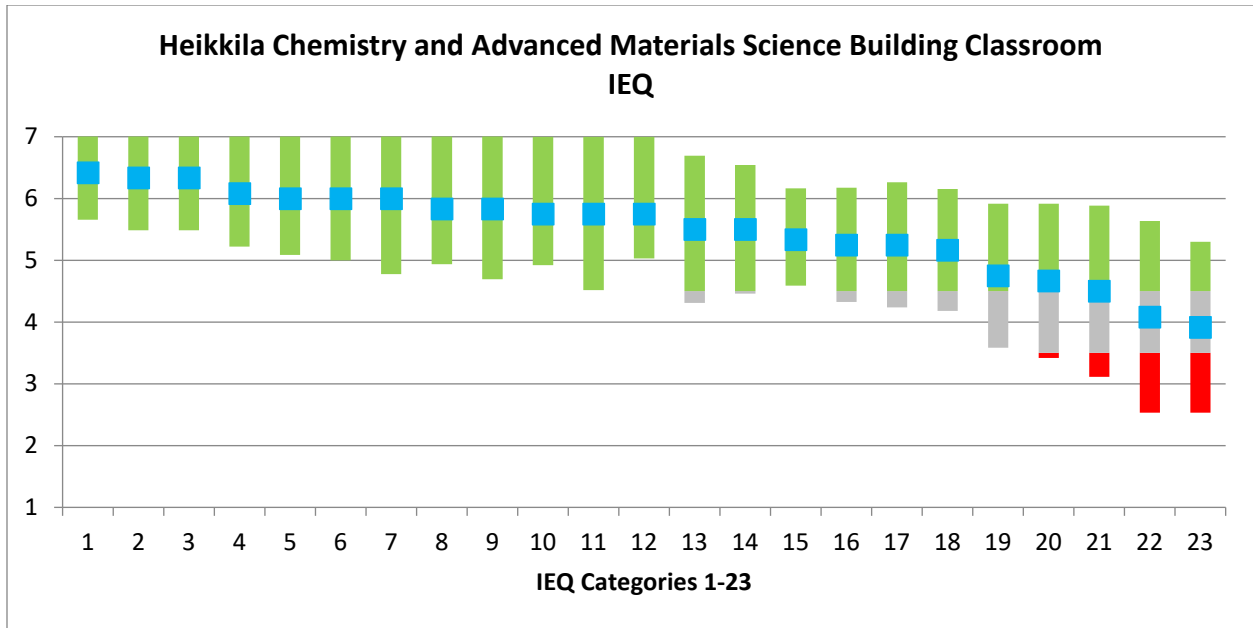
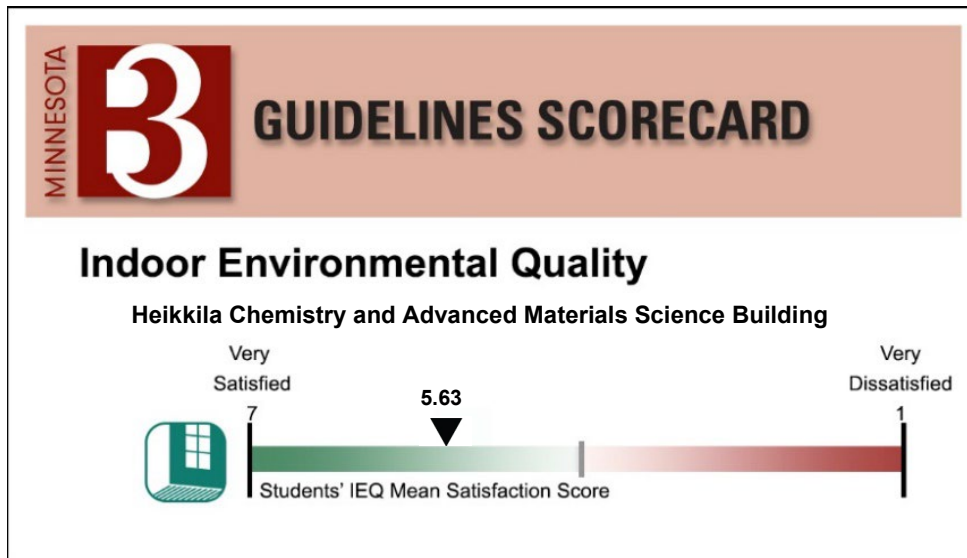


Figure 4. HCAMS primary classroom/laboratory - satisfaction with IEQ criteria (IEQ 1-23 are listed in Table 3)

Results indicate that students were **satisfied** with 21 of the IEQ criteria in their primary classroom/laboratory. Satisfied means ranged from **6.42** (amount of daylighting) to **4.50** (overall thermal conditions), i.e., means at or above 4.50. Students were **neither satisfied nor dissatisfied** with two (2) of the IEQ criteria in their primary classroom/laboratory. Neither Satisfied nor Dissatisfied means ranged from **4.08** (adjustability of thermal conditions) to **3.92** (temperature), i.e., means below 4.49 and above 3.5. Students were **dissatisfied** with zero of the IEQ criteria in their primary classroom/laboratory. These findings support **satisfaction** with the IEQ of their primary classroom/laboratory. Further information about their perceptions can be found in Appendix A. Open-Ended Responses.

4.4 IEQ Satisfaction Scorecard

The IEQ Satisfaction Score is determined by calculating a mean of all 11 category level IEQ criteria. At this time, all criteria are weighted equally in this calculation as little evidence exists that provides rationale for weighting some criteria heavier than others. The IEQ mean can serve as a benchmark of students' satisfaction with the physical environment of their primary classroom. As shown in Figure 5, the **IEQ Satisfaction Score** for HCAMS is **5.63** which falls in moderately high end of **satisfied** ratings. The large number of criteria with scores above the mean contribute to this high IEQ Score.



Overall, the students showed a relatively high positive satisfaction level with the IEQ of HCAMS laboratories and classrooms as indicated by the mean score of **5.63**. As shown in Table 3, 11 IEQ categories were at or above **5.0**, 6 categories were at or above **6.0** and helped to increase the IEQ Score. Please note that the IEQ Satisfaction Score only uses the category level criteria (those labeled ‘Overall’; see section 2.1, paragraph 3 for explanation). This IEQ score sets a positive benchmark for continued assessment of students’ satisfaction.

5.0 Physical Activity Engagement and Commuting Practices

In the final section of the survey, students responded to questions regarding their overall physical activity while at HCAMS (site, building, and interior) and their commuting practices.

5.1 Physical Activity Engagement

Providing students with opportunities for alternative paths of travel around the classroom building, e.g., taking stairs as opposed to the elevator, provides opportunities to engage in additional types of physical activities. Engaging in physical travel throughout the learning environment can be associated with healthier lifestyles.

Table 4. Overall physical activity (walking, stair use, etc.) affected by the HCAMS facility

HCAMS Facility (Site, Building, and Interior)	Mean	SD	N	Interpretation
Overall physical activity (walking, stair use, etc.)	5.36	1.07	11	Enhanced

Results indicate that students felt that HCAMS **enhanced (M = 5.36)** their physical activities (walking, stair use, etc.).

5.2 Commuting Practices

The HCAMS facility resides in the southern end of the University of Minnesota-Duluth campus. The campus is dense and compact, allowing easy pedestrian access between student residences and classroom buildings. The campus area is also served by University circulator bus routes and by Duluth Transit Authority buses, and many buildings are connected by skyways or tunnels. HCAMS has vehicle parking adjacent to the building.

Table 5 provides results on students' primary mode of transportation; Table 6 summarizes commuting distances between home and the HCAMS facility; and Table 7 summarizes students' ability to commute using alternative choices (walk, public transit, bike, van, or carpool, etc.). These results, although not related to IEQ, do offer insight into students' commuting behaviors and opinions. These data can provide important information about commuting practices that can reduce transportation energy consumption.

Table 5. Commuting practices – HCAMS primary mode of transportation

Commuting Practices Home to HCAMS (N=11)	Walk	Drive alone	Bicycle	Carpool or Vanpool
Students commuting mode (%)	55%	18%	18%	9%

Related to primary modes of transportation, 55% walk, 18% drive alone, 18% ride a bicycle, 9% carpool or vanpool. (Due to rounding error, the percentage does not equal 100%.)

Table 6. Commuting practices – HCAMS commuting distance traveled

Miles Traveled One Way (N=11)	0-5	6-15	16-30	31-45	>76
Students commuting distance (%)	100%	0%	0%	0%	0%

Results indicate that 100% of students commute 0-5 miles one-way between home and HCAMS.

Table 7. Commuting practices – HCAMS location and alternative commuting behaviors

HCAMS Facility (Site, Building, Interior)	Mean	SD	N
Ability to commute in alternative ways	4.81	1.03	11

Results indicate that the location of the HCAMS **enhanced (M = 4.81)** students' ability to commute to class in alternative ways, e.g., walking, public transit, bicycle, etc.

6.0 Conclusions

6.1 Summary

A post-occupancy evaluation was conducted of students of HCAMS at approximately 42 months after its initial occupancy in August 2019. About 13% of the students who are enrolled in classes in HCAMS responded to the survey.

The survey included questions related to students' overall satisfaction with the facility (site, building, and interior) and influence of the facility on their overall learning experience and health. Students were **satisfied** with the facility (**M = 6.50**); they found the facility **enhanced** their overall learning experience (**M = 5.33**) and **enhanced** their overall health (**M = 4.75**). When students were asked these same questions about their primary laboratory or classroom, they reported overall **satisfaction (M = 6.17)** with their primary laboratory or classroom. They also reported that their overall learning experience was **enhanced (M = 5.83)** by their primary classrooms, and their overall health was **enhanced (M = 4.75)** by their primary laboratory or classroom. As the range of scores was from 1-7, these scores indicate satisfaction is moderately high.

Most of the survey questions related to students' satisfaction with the IEQ criteria in their primary

laboratories or classrooms. Students' responses showed they were **satisfied** with 21 of the IEQ criteria. The scores ranged from **3.92** (temperature) to **6.42** (amount of daylight) Overall, these means indicate a moderately high level of satisfaction.

From the students' responses, an IEQ Score was developed and shows their **satisfaction** with the IEQ of all category level criteria. For HCAMS, the IEQ Satisfaction Score was **5.63** This score reflects a **Moderately high satisfaction** level with IEQ categories. Finally, students reported that HCAMS **enhanced (M=5.36)** their physical activity, which is one of the sustainable design criteria that influences occupant behavior.

6.2 Recommendations

The satisfaction scores are certainly in the positive direction; however, it is important to continuously work on IEQ criteria before there is dissatisfaction. For example, for IEQ categories that have physical measurement possible, e.g., thermal, acoustic, and lighting, it is recommended that these measurements be taken in classrooms. Other recommendations follow that could help the University keep occupants' satisfaction positive.

Acoustic Conditions

- Identify acoustic criteria for overall requirements.
- Determine if any task areas differ now from their original spatial layout/use (e.g., classrooms adjacent to noisy spaces).
- Develop specialized acoustical performance requirements to support functional programming occupants' tasks (e.g., sources of recurrent noise that need to be controlled, special user populations that may have distinct auditory performance limitations, or multiple uses of building spaces that may have different acoustic criteria). Identify and apply appropriate acoustics modeling software for the project.
- Measure acoustic performance onsite with full building systems (heating, ventilation, and air conditioning) running.
- Identify occupants' privacy concerns via focus groups and/or log complaints relative to acoustical conditions for further evaluation.
- Consider occupants' tasks within shared spaces to determine if spatial layout changes can be made for increased acoustic control.

Personal Adjustability

- Determine if adjustability issues arise with temperature, lighting, or furnishings via a focus group.
- Identify personal, individual problem areas and relate them to other IEQ issues via a log of complaints relative to adjustability.
- Provide education to occupants about any existing/achievable adjustment options, e.g., furnishings, air diffusers, lighting, temperature control, etc.

Thermal Conditions

- Measure thermal performance conditions on site.
- Log complaints related to thermal conditions for further evaluation.

- Determine special thermal comfort requirements or problems that may be encountered in the building due to physicality of work activities, duration of sitting, or design/layout considerations. Focus groups can be useful in identifying problem locations.
- Determine if any occupants' task areas differ now from original layout to determine if air flow is meeting systems design intent.
- Review conditions that affect thermal comfort using ASHRAE Standard 55-2004 or Human Factors Design Handbook (see B3 Guidelines).

This study investigated students' satisfaction with the HCAMS facility and primary laboratories and classrooms. IEQ satisfaction is individual, but the results of the survey show a central tendency to high satisfaction with the facility and IEQ criteria. The results can be used as a diagnostic tool to aid in continuously improving IEQ conditions for students and to set the benchmarks from which improvement can be measured in the future.

Appendix A. Open-Ended Responses

Students had the opportunity to raise specific concerns on the overall facility and their primary laboratories and classrooms. Important information can be gleaned from the numerous, open-ended survey responses. HCAMS students raised some concerns in addition to positive comments related to appearance (aesthetics) and daylighting/electric lighting and lighting controls. Generally, the comments are shown exactly as written.

Overall Positive/Negative

- The building looks great and is an amazing place to work, teach, and learn.

Acoustics and Privacy

- The ability for undergrads to rent out the private study areas would be beneficial. I have had multiple zoom calls and interviews while on campus and had to ask my adviser to check one out for me.

Daylighting/Electrical Lighting and Lighting Controls

- Some lighting in labs randomly decreases and/or increases in intensity.
- Love all the natural lighting!

Furnishings

- It would be nice to have whiteboards by the study areas on each side.
- Something else that would be nice - A hook and shelf in the individual bathrooms for backpacks and other stuff.

Operations and Cleaning/Maintenance

- There are a few places where the drywall is popping. May be in need of a touch up.
- It is weird that the trash container for batteries is just sitting on the floor in the hallway.

Technology/Electrical

- Outlets on the floors or on tables that are in 318 and 218 by the projector (I think the tables with computers already on them have the outlets, but it would be nice to have open tables with outlets).

Thermal Conditions and Control

- Lab 318 tends to all of a sudden get really cold after it had been really hot.
- The third-floor study areas get very very hot but then the second and first can get very cold.

Appendix B. Glossary

Descriptive statistics

Statistics used to summarize large sets of data (i.e., means, frequencies, medians). Descriptive statistics describe only the sample under consideration and are not intended to infer results to the larger population.

Frequency

A descriptive statistic that provides information about how many of a particular response or measurement are observed.

Likert-type scale

A measurement technique, employed in questionnaires and interviews, that utilizes a range of standardized response categories such as strongly agree, agree, etc.

Mean

The average score of a set of data calculated by adding all scores together, then dividing by the number of scores.

N

The number of subjects or participants responding to the questions, or a single question, in the study.

Reliability

The repeatability or replicability of findings; the same results are produced each time. Instruments and procedures should produce the same results when applied to similar people in similar situations, or on a second occasion.

Standard deviation

A statistic used to measure the variability of a group of scores (how different scores are from each other and the mean). For example, if the range of scores is 1-7 and the mean (average) is 5.0 with a standard deviation of 1.0, then the scores are closely clustered around the mean, i.e., there is one unit of variation among all scores. If the mean was 5.0 and the SD was 3.0, there is a broader range of variation among the scores...a smaller SD means the scores are similar and the mean score is likely to be more accurate and more useful (this is better!).

Validity

The extent to which an instrument or procedure measures what it is intended to measure (internal validity). The generalizability of results to another population (external validity).