Indoor Environmental Quality + Workplace Environment
UMD Heikkila Chemistry and Advanced Materials Science Building (HCAMS)
Duluth, MN

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 (HCAMS) facility and occupants' satisfaction with their work environments located in the facility. This report communicates responses from employees about the overall facility and their workplace (WP). The facility was designed using the 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 work 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 employees) responses nearly 44 months post-occupancy. The survey was conducted in June 2023.

This SPOES report focuses on employees' satisfaction with the physical environment as related to 26 indoor environmental quality (IEQ) criteria such as lighting, thermal, and acoustic conditions in their primary workspaces, i.e., offices. Employees' satisfaction with the facility (site, building, and interior) and the effect of the facility's physical environment on their perceptions of their work performance and health also are included. Finally, a brief look at employees' commuting and physical activities within the building are reported. The report provides descriptive information about employees' perceptions of the IEQ of their work environments. In addition, this information serves the broader development of knowledge regarding the influence of IEQ on employees.

2.0 Method

SPOES consists of a self-administered, Internet-based questionnaire submitted to and completed by employees. The SPOES questionnaire has been tested for **validity** (measures what it is intended to measure) and **reliability** (repeatability or replicability of findings). Employees 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 workspaces. They also rate the influence of their physical environment on their perception of their work 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 enhanced)
- 4.51 - 7.00 satisfied (or enhanced)

An IEQ Score is also calculated for employees' satisfaction with IEQ criteria in their primary workspaces. This is a statistical combination of all category-level (explained below) 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

Employees 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 work performance and health. Then they respond to questions about their satisfaction with their primary workspaces in relation to IEQ criteria from the B3 Guidelines. Additionally, employees' demographic, physical activity, and commuting practice data are collected to provide context for the study.

In the SPOES questionnaire, the 26 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 attributes of employees' ability to hear desired sounds and their ability to limit undesired sounds. There are 12 category-level and 14 attribute level questions. Means are calculated and reported for all category and attribute-level criteria.

An IEQ Satisfaction Score is also calculated for employees' satisfaction with IEQ in their primary workspaces. This is a statistical combination of the 12 category-level criteria only and results in a single, mean IEQ Satisfaction Score for all employees' satisfaction with the physical conditions of their primary workspaces. 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
- Ability to limit undesired sounds

Overall Appearance (aesthetics)

Overall Cleaning and Maintenance

Overall Daylighting Conditions
- Amount of daylighting
- Adjustability of daylighting

Overall Electric Lighting Conditions
- Amount of electric lighting
- Adjustability of electric lighting
- Adjustability of task lighting

Overall Furnishings
- Function of furnishings
- Adjustability of furnishings

Overall Indoor Air Quality

Overall Privacy

Overall Technology
- Access to electric outlets

Overall Thermal Conditions
- Adjustability of thermal conditions
- Air velocity (drafty/stagnant)
- Humidity (dry or moist)
- Temperature (hot or cold)

Overall Vibration and Movement

Overall View Conditions

2.2 Limitations

Employees' participation is voluntary, and responses are self-reported. As is true with all survey research, the responses indicate employees' perceptions. There were no physical measurements, e.g., temperature, humidity, or lighting levels of the environment taken. This study is limited to employees' 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. This building provides approximately 4,500 ft2 of workspace for faculty and staff. To support faculty and staff, the workplace also includes conference and collaborative space, as well as support areas.

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

This survey was administered to 27 employees with workspace in the facility during the spring semester of 2023. The response rate to the questionnaire was approximately 48%. Of those responding, 58% were male and 42% were female. The mean age of respondents was 45 years, with a range from 26-69 years of age.

The HCAMS is a workplace with enclosed private or shared offices and work areas in labs.

83% of the respondents reported that they worked in HCAMS for more than two years and 17% of the respondents reported that they worked at the HCAMS facility for 1-2 years. Relating to hours worked during a typical week at the HCAMS facility, 83% spend 30-40 hours a week at HCAMS, and 17% spend 20-29 hours at the facility.

Relating to the time employees spend per week in their primary workspace, 42% of the employees reported they spend more than 75% of their weekly time in their primary workspace; over 42% spend 51-75% of their time in their primary workspace; and 17% spend 25-50% of their time in their primary workspace. These responses indicate the amount of time employees are exposed to IEQ conditions in their workplace environment.

100% of employees indicated that their primary workspaces were located within 15 feet of an exterior window.

4.0 Findings and Discussion

4.1 HCAMS Facility (Site, Building, and Interior): Overall Satisfaction, Work Performance, and Health

Employees responded to questions concerning the HCAMS facility (site, building, and interior) and their overall satisfaction with the facility, overall perceptions of their work performance 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, which is identified with a blue mark. The standard deviation is shown by the 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 may be all green or gray and green. This graph is simply a visual image of the findings from Table 1.

Overall	Mean	SD	N	Interpretation
Satisfaction	5.46	1.60	13	Satisfied
Work Performance	5.23	1.58	13	Enhances
Health	5.08	1.00	13	Enhances

Table 1 HCAMS facility - overall satisfaction, work performance, and health

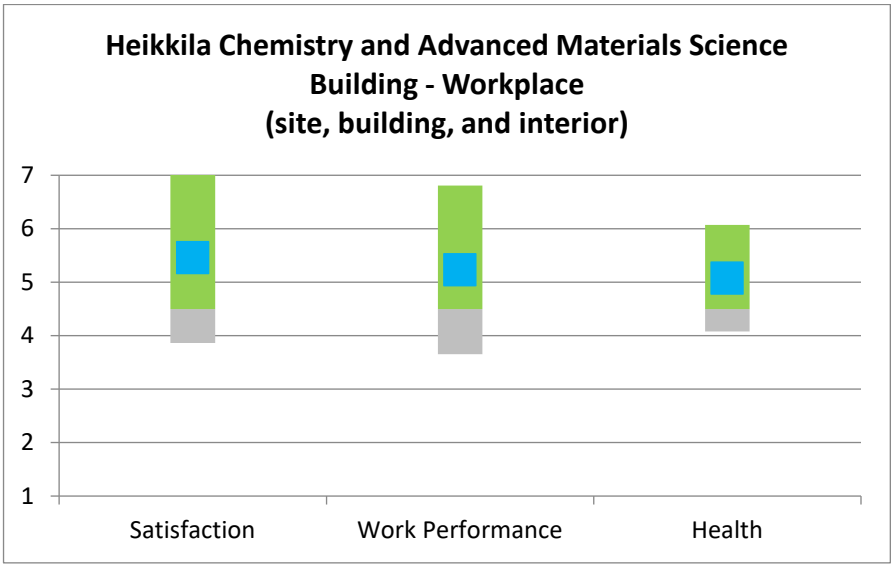

Figure 2. HCAMS facility - overall satisfaction, work performance, and health

Results indicate that employees were **satisfied** (**M =5.46**) with the physical environment of the HCAMS facility (building, site, and interior) and reported that their overall work performance was **enhanced** (**M =5.23**) by the facility. Employees reported that their overall health was **enhanced** (**M =5.08**) by the facility. *Note: the higher standard deviation (SD) relative to satisfaction and work performance indicates more variation in employees' perceptions about that factor (greater dispersal of data points).

4.2 Primary Workspace: Overall Satisfaction, Work Performance, and Health

Employees responded to questions concerning their overall satisfaction and overall perceptions of their work performance and health as related to their primary workspace (e.g., private office, workstation, or other primary workspace). 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; an explanation of the graph was given for Figure 2.

Overall	Mean	*SD	N	Interpretation
Satisfaction	5.54	1.08	13	Satisfied
Work Performance	5.46	1.55	13	Enhances
Health	4.85	1.03	13	Enhances

Table 2. HCAMS primary workspace – overall satisfaction, work performance and health

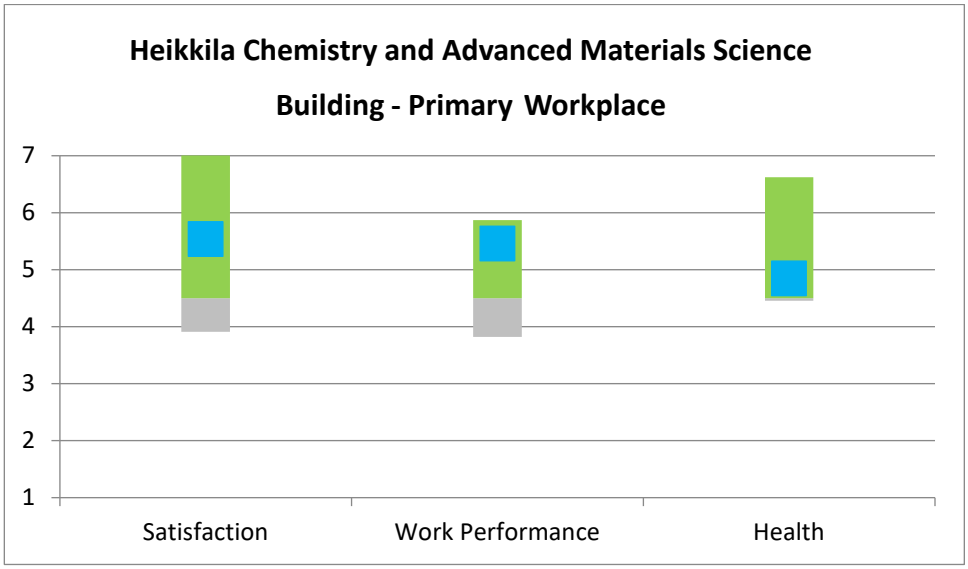

Figure 3. HCAMS primary workspace - overall satisfaction, work performance, and health

Results indicate that employees were **satisfied** (**M =5.54**) with their primary workspace, their overall work performance was **enhanced** (**M =5.46)** by their primary workspace, and their overall health was **enhanced** (**M =4.85**) by their primary workspace. *Note: the higher standard deviation (SD) relative to work performance indicates more variation in employees' perceptions about those factors (greater dispersal of data points).

4.3 Primary Workspace: Satisfaction with Indoor Environmental Quality (IEQ)

Employees responded to questions concerning their satisfaction with IEQ categories (thermal conditions, indoor air quality, acoustic conditions, etc.) related to their primary workspace (e.g., private office, workstation, or other primary workspace). Table 3 shows the means and standard deviations of their responses from highest to lowest mean, as well as how the responses are interpreted. Figure 4 is a visual image of the findings from Table 3; an explanation of the graph was given for Figure 2.

#	**IEQ Criteria (1-26)** (Category level criteria are **bold** face)	**Mean**	***SD**	**N**	**Interpretation** (D=Dissatisfied) (S=Satisfied)
1	**Overall daylighting**	5.92	1.07	13	Satisfied
2	Amount of daylighting	5.92	1.00	13	Satisfied
3	Adjustability of daylighting	5.77	1.05	13	Satisfied
4	**Overall cleaning and maintenance**	5.77	1.37	13	Satisfied
5	**Overall vibration and movement**	5.69	1.14	13	Satisfied
6	Ability to hear desired sounds	5.46	1.01	13	Satisfied
7	**Overall technology conditions**	5.46	1.28	13	Satisfied
8	Air velocity (drafty or stagnant)	5.38	1.50	13	Satisfied
9	**Overall indoor air quality**	5.38	1.73	13	Satisfied
10	**Overall appearance (aesthetics)**	5.33	1.89	12	Satisfied
11	Humidity (dry or moist)	5.31	1.26	13	Satisfied
12	**Overall acoustic quality**	5.17	1.46	12	Satisfied
13	Ability to limit undesired sounds in your primary workspace	5.08	1.44	12	Satisfied
14	Function of furnishings	5.00	1.52	13	Satisfied
15	Access to electric outlets	5.00	1.41	13	Satisfied
16	Amount of electric light	4.92	1.77	13	Satisfied
17	**Overall privacy (sound and visual privacy) conditions**	4.92	1.59	13	Satisfied
18	**Overall furnishings**	4.92	1.73	13	Satisfied
19	**Overall view conditions**	4.85	1.61	13	Satisfied
20	**Overall electric lighting conditions**	4.62	1.98	13	Satisfied
21	Ability to adjust electric lighting	4.62	1.98	13	Satisfied
22	Adjustability of furnishings	4.38	1.86	13	Neither S nor D
23	**Overall thermal conditions**	4.36	2.14	11	Neither S nor D
24	Adjustability of your task lighting	3.85	1.79	13	Neither S nor D
25	Temperature (hot or cold)	3.69	2.05	13	Neither S nor D
26	Adjustability of thermal conditions	2.23	1.85	13	Dissatisfied

Table 3. HCAMS primary workspace - satisfaction with IEQ criteria

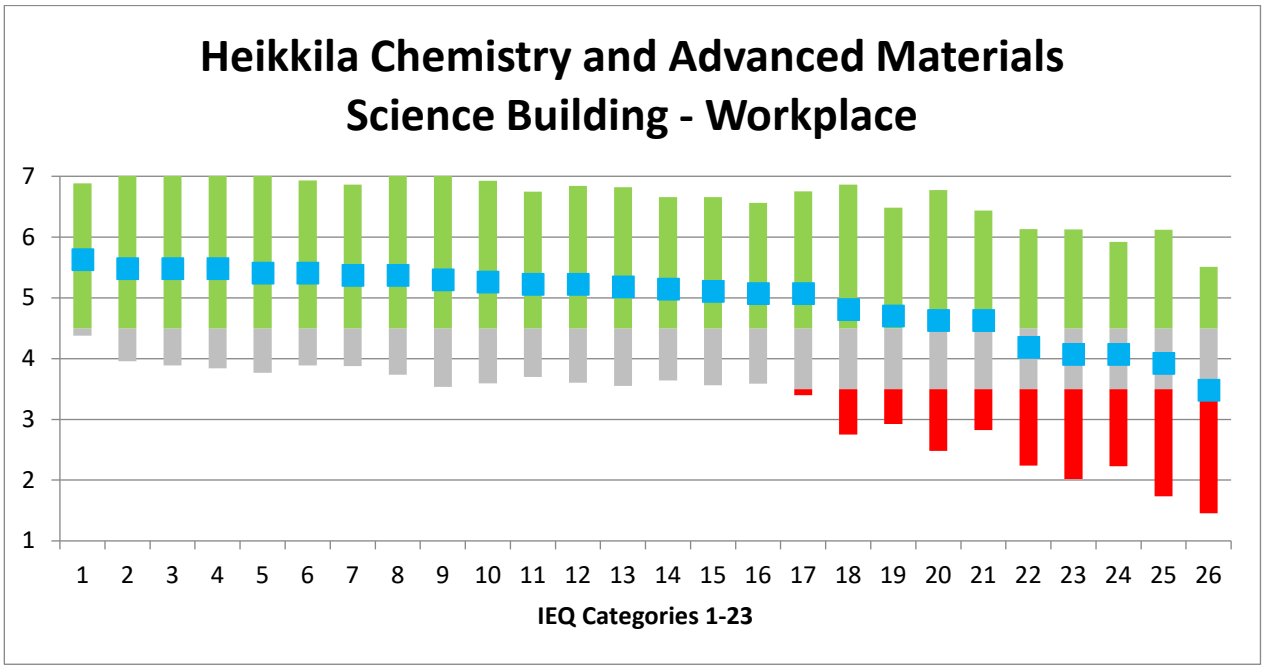

Figure 4. HCAMS primary workspace - satisfaction with IEQ criteria (IEQ 1-26 refer to Table 3)

Results indicate that employees were **satisfied** with 21 of the IEQ criteria in their primary workspaces, i.e., means at or above 4.50. Satisfied means ranged from **5.92** (Overall daylighting) to **4.62** (ability to adjust electric lighting). Employees were **neither satisfied nor dissatisfied** with 4 IEQ criteria, ranging from a mean of **4.38** (adjustability of furnishings) to **3.69** (temperature). Employees were **dissatisfied** with 1 of the IEQ criteria, with a mean of **2.23** (adjustability of thermal conditions). *Note: the higher standard deviations (SD) relative to over half of all the IEQ criteria measures indicate more variation in employees' perceptions about criteria (greater dispersal of data points). Specific primary workplace location and immediate, surrounding environmental conditions are likely the cause for these degrees of greater variation (SD > 1.50).

The criteria in the 'neutral' satisfaction range should be considered for change in addition to that in the dissatisfied range; together they comprise 5 of the 26 IEQ criteria. Potential for change will be addressed in Section 6.2 Recommendations. Further explanation of these scores also can be found in Appendix A. Open-Ended Responses.

Employees also responded to more specific and detailed questions concerning their satisfaction with lighting and daylighting conditions in their primary workspace (e.g., private office, workstation, or other primary workspace). Table 4 shows the means and standard deviations of their responses from highest to lowest mean, as well as how the responses are interpreted. Figure 5 is a visual image of the findings from Table 4; an explanation of the graph was given for Figure 2.

#	**Lighting and Daylighting Criteria 1-5**	Mean	SD	N	**Interpretation** (D=Dissatisfied) (S=Satisfied)
1	Visual comfort (absence of glare, shadows, flickers) of the electric light	5.85	1.10	13	Satisfied
2	Amount of noise (humming, clicking, etc.) produced by electric light fixtures	5.85	1.10	13	Satisfied
3	Ease of turning electric lights on and off	4.15	1.99	13	Neither S nor D
4	Quality of task lighting	3.85	1.99	13	Neither S nor D
5	Effectiveness of automatic lighting sensors (speed of sensing, reaction to movement, etc.)	3.69	1.94	13	Neither S nor D

Table 4. HCAMS primary workspace - satisfaction with lighting and daylighting IEQ criteria

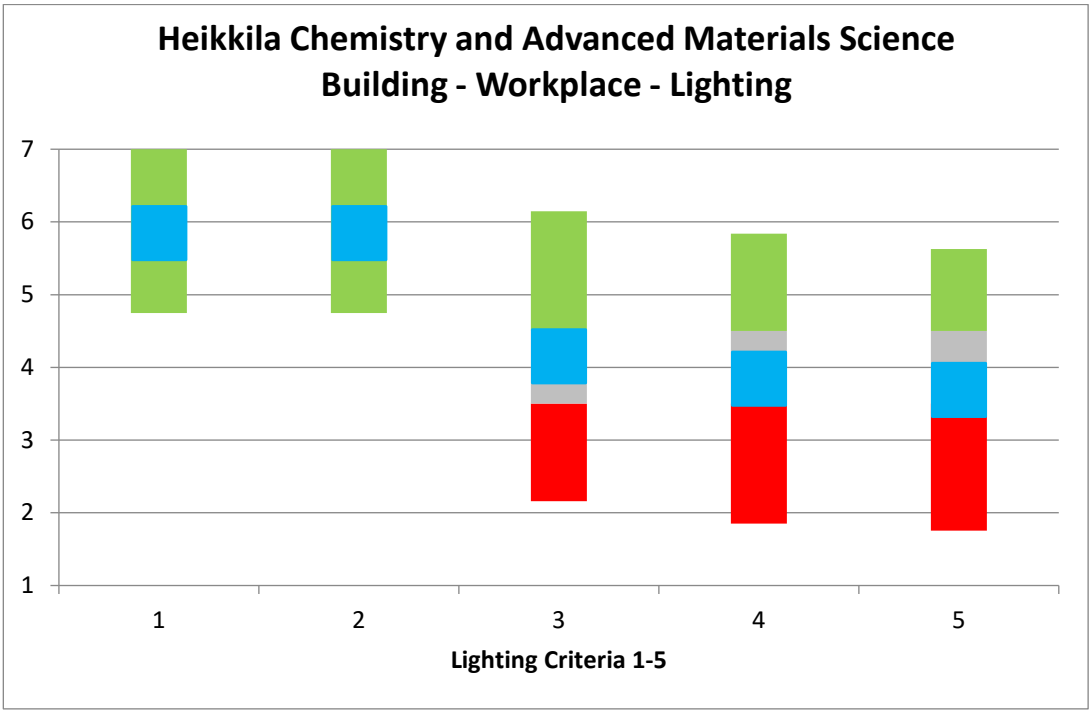

Figure 5. HCAMS primary workspace - satisfaction with lighting and daylighting IEQ criteria (Lighting Criteria 1-5 refer to Table 4)

4.4 Primary Workspace: Lighting and Daylighting, Work Performance, and Health

Employees responded to questions concerning their overall perceptions of their work performance and health as related to the lighting and daylighting conditions in their primary workspace (e.g., private office, workstation, or other primary workspace). Table 5 shows the means and standard deviations of their responses as well as how the responses are interpreted. Figures 6 and 7 are visual images of the findings from Table 5; an explanation of the graph was given for Figure 2.

Overall	Mean	SD	N	Interpretation
Daylighting:				
Work Performance	5.77	0.97	13	Enhances
Health	5.31	1.07	13	Enhances
Electric Lighting:				
Work Performance	4.62	1.60	13	Enhances
Health	4.62	0.92	13	Enhances

Table 5. HCAMS lighting and daylighting in primary workspace – impact on work performance and health.

Results indicate that employees reported that their overall work performance and health were **enhanced** (**M =5.77, M=5.31**) by the daylighting. Employees reported that their overall work performance and health were also **enhanced** (**M =4.62, M=4.62**) by the electric lighting. *Note: the higher standard deviation (SD) relative to work performance indicates more variation in employees' perceptions about those factors (greater dispersal of data points).

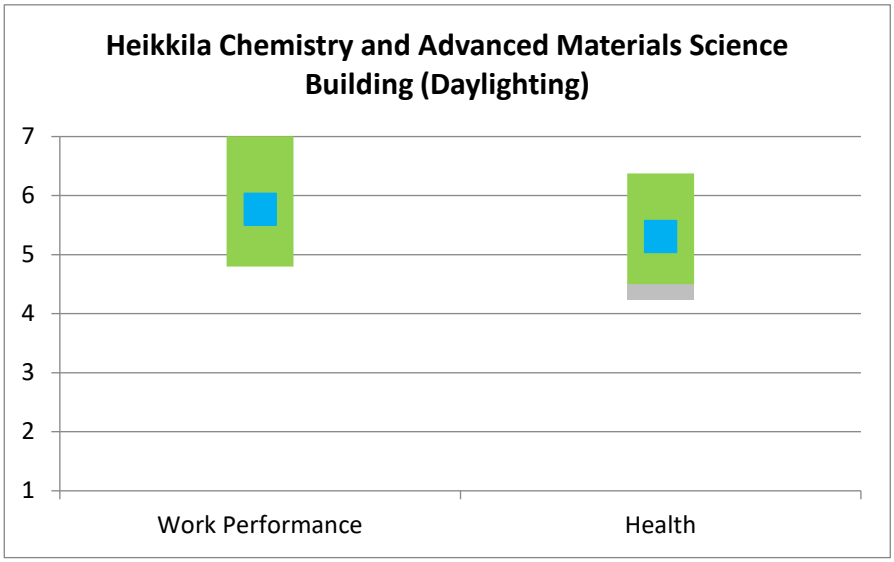

Figure 6. HCAMS primary workspace - daylighting impact on work performance and health

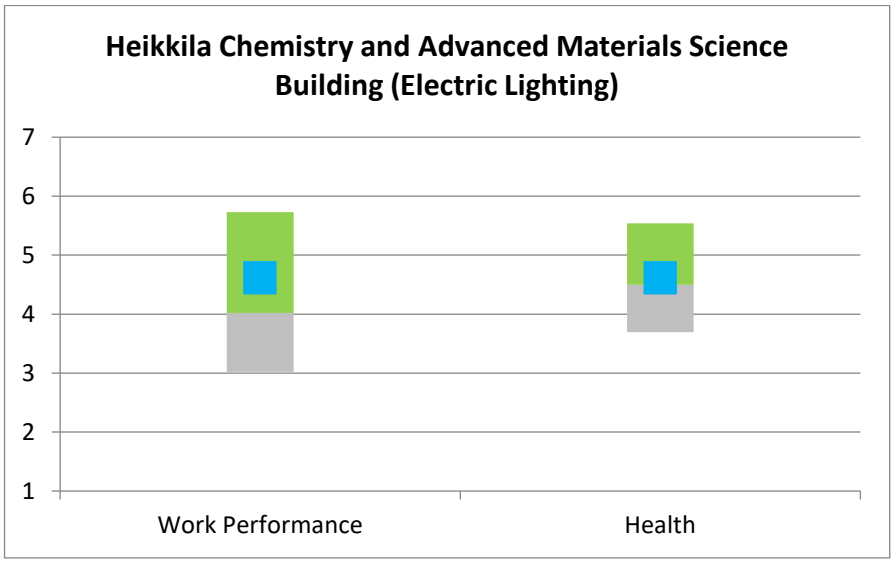

Figure 7. HCAMS primary workspace – electric lighting impact on work performance and health

4.5 IEQ Satisfaction Scorecard

The IEQ Satisfaction Score is determined by calculating a mean of the 12 'Overall' category level IEQ criteria. At this time, criteria are weighted equally in this calculation as little evidence exists that provides rationale for weighting some criteria heavier than others. The IEQ mean is representative of a fair overall IEQ score and can serve as a benchmark of employees' satisfaction with the physical environment of their primary workspace. As shown in Figure 5, the **IEQ Satisfaction Score** for the HCAMS is **5.20**, in the **Satisfied** range**.**

Figure 8. HCAMS primary workspace - IEQ Satisfaction Score

As shown in Table 3, satisfaction with the Overall daylighting, cleaning and maintenance, vibration and movement, technology conditions, indoor air quality, and appearance were the categories with the highest satisfaction means (5.33 or higher), in the satisfied mid-range. In combination with the remaining 6 somewhat lower mean scores (5.17 – 4.62), the satisfied scores were successful in pulling the IEQ Satisfaction Score in a positive direction. The remaining mean score was in the neutral range, 4.36 (Overall thermal conditions). Please note that the IEQ Satisfaction Score only uses the category level criteria (those labeled 'Overall'; see section 2.1, paragraph 3 for explanation).

5.0 Physical Activity Engagement and Commuting Practices

In the final section of the survey, employees 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 employees with opportunities for alternative paths of travel around the workplace, 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 work environment can be associated with healthier lifestyles.

Table 6. Overall physical activity (walking, stair use, etc.) affected by the HCAMS facility

HCAMS (site, building, and interior)	Mean	SD	N	Interpretation
Overall physical activity (walking, stair use, etc.)	5.54	1.22	13	Enhances

Results indicate that employees felt that HCAMS **enhanced** (**M = 5.54**) 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 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. Note that the overall percentages may not total 100%, due to rounding.

Table 7 provides results on employees' primary mode of transportation; Table 8 summarizes commuting distances between home and the HCAMS facility; and Table 9 summarizes employees' 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 employees' commuting behaviors and opinions. These data can provide important information about commuting practices that can reduce transportation energy consumption.

Primary Mode of Transportation (N=13)	Drive Alone	Bicycle
Commuting to HCAMS	89%	11%

Table 7. Commuting Practices – HCAMS Primary mode of transportation

Related to primary modes of transportation, 89% of employees drive alone, and 11% of employees ride a bicycle.

Miles Traveled (N=13)	**0-5**	**6-15**	**16-30**	**31-45**
Home-to-HCAMS (One-way)	62%	23%	8%	8%

Table 8. Commuting Practices – HCAMS Commuting distance traveled

Results indicate that 62% of employees commute 0-5 miles one-way between home and the HCAMS, followed by 23% who commute 6-15 miles, 8% who commute 16-30 miles and 8% who commute 31-45 miles. These are one-way miles.

Alternative Commuting	**Mean**	**SD**	**N**	**Interpretation**
Ability to commute in alternative ways	5.54	1.22	13	Enhances

Table 9. Commuting practices – HCAMS location and alternative commuting behaviors

Results indicate that location of the HCAMS **enhances (M = 5.54)** employees' ability to commute to work in alternative ways, e.g., walk, bicycle, public transit, van or carpool, etc.

6.0 Conclusions

6.1 Summary

A post-occupancy evaluation was conducted of employees of the HCAMS at approximately 44 months after its initial occupancy in August 2019. About 48% of faculty and staff responded to the survey, reporting their satisfaction with the physical environment of the facility and their primary workspace. Results indicate that 83% of employees spend more than 30 hours per week in the HCAMS facility, and 84% of employees spend more than 50% of their time at the HCAMS in their primary workspace.

The survey included questions related to employees' satisfaction with the facility (site, building, and interior) and the influence of the facility on their work performance and health. Employees were **satisfied** with the facility **(M = 5.46)**; they found the facility **enhanced** their work performance **(M = 5.23)** and **enhanced** their health **(M = 5.08)**. In addition, similar results were reported when employees were asked these same questions about their primary workspaces (private offices, shared offices, workstations, etc.). They reported **satisfaction (M = 5.54)** with their primary workspaces, that their work performance was **enhanced (M = 5.46)**, and their health was **enhanced (M = 4.85)** by their primary workspace. As the range of scores was from 1-7, the majority of scores showed a moderate level of satisfaction with the facility and a moderate level of satisfaction with the primary workspace. (The satisfaction/enhancement range is 4.51-7.00, whereas the neutral range is 3.51-4.50.) Facility satisfaction and work performance, and primary workspace work performance had means with higher standard deviations (SD = 1.55–1.60), indicating a broader variation in their responses (greater dispersal of data points).

Most of the survey questions related to employees' satisfaction with the IEQ criteria in their primary workspaces (private office, workstations, etc.). Employees' responses showed they were **satisfied** with 21 of the 26 IEQ criteria. The mean satisfaction scores ranged from **5.92** (overall daylighting) to **4.62** (ability to adjust electric lighting). Again, this shows a moderate positive level of **satisfaction**. Employees responded **neither dissatisfied nor satisfied** to 4 IEQ criteria, with mean satisfaction scores ranging from **4.38** (adjustability of furnishings) to **3.69** (temperature). The remaining IEQ criterion fell within the dissatisfied range at 2.23 (adjustability of thermal conditions). Again, there was variation among responses that drove up the standard deviations (SD = 1.50-2.14), indicating greater dispersal of data points among 15 of the 26 IEQ criteria scores. This was also true of the IEQ criteria category scores that comprised the IEQ Scorecard, discussed below.

From employees' responses, an IEQ Score was developed and shows respondents' moderate satisfaction with the majority of all IEQ category level criteria. For the HCAMS, the IEQ Satisfaction Score was **5.20**. This score reflects the influence of the moderate satisfaction level of 11 of the 12 categories, and the neither dissatisfied nor satisfied level of 1 of the 12 IEQ categories. Finally, employees reported that the HCAMS **enhanced (M=5.54)** their physical activity, which is one of the sustainable design criteria that influences occupant behavior.

It seems obvious that employees' satisfaction can be improved by addressing the categories that had 'neither dissatisfied nor satisfied' or 'dissatisfied' scores. However, the rest of the criteria would benefit from some attention as well. The following recommendations can help address these criteria to further improve employees' satisfaction. Exploring these areas in more detail and making adjustments may increase overall satisfaction in the primary workspace. It must be noted that the expense of building and operating a facility is second only to employee-related expenses over the life of the building.

Therefore, maintaining or improving employees' satisfaction is a sound investment, which, in turn, affects their performance and their health.

This study investigated employees' satisfaction with the facility and primary workspaces. IEQ satisfaction is individual, but the results of the survey show a central tendency of moderately lower satisfaction with the facility and most of the IEQ categories. The results can be used as a diagnostic tool to aid in improving IEQ conditions for employees and to set the benchmarks from which improvement can be measured in the future.

6.2 Recommendations

Several IEQ criteria satisfaction scores are in the positive direction, however, improvement on the 'neutral' and 'dissatisfied' criteria may be possible. For IEQ categories that can be physically measured (e.g., thermal, acoustic, and lighting), it is recommended that these measurements be taken in the primary workspaces. Specific recommendations for the most common areas of occupants' concern follow:

Lighting Conditions

- Identify employees' lighting performance criteria that are to be met to achieve goals by conducting onsite measurements of existing illumination and compare them to standards for employees' tasks as identified by the Illuminating Engineering Society (IES).
- Determine if any task areas differ now from original intent to be sure illumination level and quality of lighting are not impeded by physical changes to the space (i.e., walls, ceilings, furnishings, fixtures, or equipment).
- Develop additional quality lighting criteria as needed for special facility (e.g., influence of daylight quality or quantity) or employee (e.g., age, task duration) issues.
- Log complaints related to lighting conditions for further evaluation.
- Identify poor lighting conditions in the workspace caused by a lack of control over daylighting, which can cause glare and eyestrain.
- Adjust electric light control system including sensors and timers.

Personal Adjustability

- Determine what 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 employees 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 employees' task areas differ now from original layout to determine if air flow is meeting systems design intent.
- Review conditions that affect thermal comfort using the applicable version of ASHRAE Standard 55, or Human Factors Design Handbook (see B3 Guidelines). For additional information, consider reviewing Human Factors and Ergonomics Design Handbook, Third Edition (2016), by Barry Tillman, published by McGraw-Hill, NY.

Appendix A. Open-Ended Responses

Employees had the opportunity to raise specific concerns about the overall facility and their primary workspaces. Important information can be gleaned from the open-ended survey responses. The HCAMS employees raised many general and very specific concerns related to daylighting/electric lighting and lighting controls, indoor air quality (IAQ)/ventilation, operations and cleaning/maintenance, and thermal conditions and control. Generally, the comments are shown exactly as written.

Daylighting/Electric Lighting and Lighting Controls

- The lights shut off randomly when you don't move enough. It can be a distraction.

IAQ/Ventilation

- It feels like any air from outside is pumped unfiltered inside as every time there is a fire or chemical smell outside it is immediately concentrated inside the building.

Operations and Maintenance/Cleaning

- Drywall needs patching.

Thermal Conditions and Control

- My office is at the end of a hallway. There's no ability to control the temperature or humidity in the workspace and there's little to no air flow in my workspace.
- Too cold in summer, impossible to adjust settings in office.
- The temperatures in different rooms are wildly different. Some labs are extremely cold constantly while others are extremely warm.

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 is observed.

Likert-type scale
A measurement technique, employed in questionnaires and interviews, 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).