Beyond Certification: A Multi-Quantitative Post-Occupancy Evaluation of Indoor Environmental Quality in a Platinum-Certified Subtropical University Building

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S1. Indoor Environmental Quality (IEQ) Satisfaction Survey

Questionnaire for Block R of MUST

Q1. Thermal Comfort (Perceived temperature appropriateness and comfort)

Q1.1 Overall satisfaction with indoor temperature?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q1.2 How satisfied are you with the seasonal adaptability of indoor temperature control, such as cooling in summer and heating in winter?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q1.3 Frequency of localized overheating/underheating?

1	2	3	4	5
Very Frequent	Frequent	Occasional	Rare	Never

Q2. Indoor Air Quality (Pollutant concentrations and health impacts)

Q2.1 Satisfaction with air freshness?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q2.2 Frequency of unpleasant odors (e.g., mildew/chemical smells)?

1	2	3	4	5
Very Frequent	Frequent	Occasional	Rare	Never

Q2.3 How frequently do you experience discomfort that you associate with indoor air quality, such as dizziness, dry eyes, or respiratory irritation?

1	2	3	4	5
Very Frequent	Frequent	Occasional	Rare	Never

Q3. Ventilation (Natural/mechanical air circulation)

Q3.1 Satisfaction with ventilation systems?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q3.2 Adequacy of natural ventilation (e.g., operable windows)?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

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Q4. Acoustic Comfort (Noise control and sound privacy)

Q4.1 How satisfied are you with the overall acoustic environment?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q4.2 How effective is the sound insulation between classrooms and adjacent indoor spaces, such as corridors or neighboring rooms?

1	2	3	4	5
Very Ineffective	Ineffective	Neutral	Effective	Very Effective

Q5. Lighting Quality (Adequacy and visual comfort)

Q5.1 How satisfied are you with the adequacy of indoor lighting levels?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

Q5.2 Adequacy of natural daylighting?

1	2	3	4	5
Very Poor	Poor	Neutral	Good	Excellent

Q5.3 How frequently do you experience visual discomfort caused by glare or insufficient lighting?

1	2	3	4	5
Very Frequent	Frequent	Occasional	Rare	Never

Q6. Overall Satisfaction with Block R's Indoor Environment:

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

S2. IEQ Satisfaction Survey: Raw Response Data

Table S1: Raw Data of the Indoor Environmental Quality (IEQ) Satisfaction Survey in MUST Block R.

Respondent ID	Q1.1	Q1.2	Q1.3	Q2.1	Q2.2	Q2.3	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q6
1	4	4	4	4	4	5	4	2	4	4	4	2	4	4
2	3	3	3	3	4	4	2	2	1	3	4	3	4	4
3	4	4	3	3	3	4	3	3	4	4	5	3	4	4
4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	4	4	5	4	5	5	4	4	4	4	4	5	4	4
6	5	5	5	4	5	5	4	4	5	4	4	4	4	5
7	3	4	3	3	3	3	3	5	3	4	4	5	3	4
8	4	3	4	3	2	3	3	1	4	2	4	2	5	3
9	4	4	3	4	3	3	3	3	4	4	4	4	3	4
10	4	4	5	3	3	3	3	1	3	2	4	2	4	4
11	5	4	3	4	4	5	4	4	5	4	4	4	4	4
12	5	5	5	5	5	5	5	4	5	5	4	5	4	5
13	5	5	5	5	5	5	5	3	5	5	5	1	5	5
14	4	4	3	2	2	2	4	1	3	4	4	3	3	4
15	4	4	3	3	4	4	3	2	3	3	3	3	4	4
16	4	4	5	4	5	4	3	1	3	2	4	3	4	4
17	4	4	5	4	5	5	4	4	4	4	5	4	5	4
18	5	5	5	4	5	5	4	4	5	4	4	4	4	5
19	4	4	2	4	5	5	4	4	5	5	5	4	5	4
20	4	4	4	3	4	5	3	1	1	2	5	1	3	4
21	5	5	5	4	3	5	4	4	3	3	4	5	4	5
22	4	4	5	4	2	5	4	4	4	4	4	4	2	4

Respondent ID	Q1.1	Q1.2	Q1.3	Q2.1	Q2.2	Q2.3	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q6
23	3	4	4	3	3	3	3	1	3	3	4	4	4	4
24	4	3	3	2	3	4	3	4	3	4	5	5	3	4
25	5	4	4	4	5	5	4	4	5	4	5	4	3	5
26	4	3	4	3	3	3	3	1	2	2	4	4	4	4
27	4	4	4	4	3	3	3	4	4	4	4	4	3	4
28	4	3	4	3	4	4	3	3	4	4	4	3	4	4
29	4	3	3	4	3	5	4	3	4	4	4	3	3	4
30	4	4	3	4	5	5	4	4	4	4	4	4	5	4
31	5	5	5	5	5	5	5	5	5	3	5	5	5	5
32	5	5	5	5	5	5	5	5	5	5	5	1	5	5
33	5	4	4	3	5	3	3	3	4	4	5	5	5	4
34	3	3	1	1	1	1	1	1	3	4	4	1	1	1
35	4	4	4	4	4	5	3	2	3	1	4	2	3	4
36	4	5	5	4	5	5	4	3	4	4	4	5	4	4
37	4	1	3	3	4	4	3	4	1	3	4	2	3	4
38	5	5	4	4	5	5	5	3	4	4	5	4	4	4
39	4	2	2	1	3	2	1	1	1	1	5	1	3	4
40	5	4	4	3	3	5	4	3	4	4	4	4	3	5
41	4	3	2	4	3	2	4	2	4	3	5	4	4	4
42	3	4	2	4	4	4	4	4	4	3	4	4	3	4
43	5	5	1	5	5	5	5	5	5	5	5	5	5	5
44	5	5	1	5	5	5	5	5	4	4	4	4	4	5
45	5	5	5	5	5	5	5	5	5	5	5	5	5	5
46	3	3	2	3	4	2	3	3	2	4	4	3	4	4
47	5	4	2	5	4	4	3	4	3	4	4	5	3	4
48	4	4	4	4	3	2	3	3	4	4	4	3	4	5

Respondent ID	Q1.1	Q1.2	Q1.3	Q2.1	Q2.2	Q2.3	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q6
49	3	4	2	5	5	5	5	5	5	5	5	5	5	5
50	5	5	1	5	2	1	5	5	5	5	5	5	2	5
51	5	5	3	1	1	2	2	5	2	3	5	2	1	4
52	4	4	2	3	4	4	3	3	3	4	4	4	4	5
53	4	4	3	2	3	3	3	3	2	4	4	3	3	4
54	4	5	4	4	5	5	4	5	5	4	5	5	5	4
55	4	3	4	5	5	5	5	4	5	5	5	4	5	5
56	5	5	2	4	5	3	4	4	4	4	4	4	4	5
57	4	4	2	4	4	3	4	4	4	4	4	4	4	4
58	4	3	2	4	4	3	4	4	4	4	5	5	3	5
59	4	4	3	5	5	5	4	2	4	4	5	3	5	5
60	4	4	2	4	4	4	4	4	3	4	5	4	5	5
61	3	3	1	3	3	2	3	2	3	3	3	3	2	3
62	4	4	1	3	4	3	3	2	4	4	4	3	2	4
63	5	5	5	4	4	5	4	5	4	5	4	4	5	5
64	4	5	3	5	4	5	4	4	4	5	5	4	5	5
65	5	5	1	5	5	5	5	5	3	5	5	5	5	5
66	5	5	5	5	5	5	5	5	5	5	5	5	5	5
67	4	4	3	4	4	4	4	3	3	3	4	4	4	4
68	5	5	4	5	5	5	4	5	5	5	5	5	5	5
69	3	2	2	4	3	4	4	3	4	3	2	3	2	4
70	4	4	3	4	4	4	4	4	4	4	4	4	4	4
71	3	4	2	5	5	5	4	4	4	4	5	4	4	5
72	3	3	3	4	5	4	4	4	3	4	4	4	2	4
73	5	5	4	4	5	5	4	5	4	3	5	5	5	5
74	3	4	2	5	4	4	4	3	5	5	3	3	2	4

Respondent ID	Q1.1	Q1.2	Q1.3	Q2.1	Q2.2	Q2.3	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q6
75	5	4	4	4	3	4	4	3	4	4	5	4	4	4
76	4	4	3	4	4	4	4	4	4	4	4	5	4	4
77	4	4	4	4	4	4	3	3	2	3	4	4	4	4
78	3	3	2	4	4	5	4	2	3	4	5	5	5	4
79	4	4	1	3	3	4	3	2	3	3	4	4	3	4
80	5	4	3	4	5	5	4	5	5	4	4	4	4	4
81	4	4	3	5	5	5	4	4	5	5	4	5	5	5
82	4	4	3	4	4	3	4	4	4	4	4	4	4	4
83	4	4	4	4	4	5	4	4	4	4	4	4	4	4
84	4	4	4	1	2	4	2	1	3	5	5	4	4	5
85	3	4	3	4	5	5	4	3	4	4	4	4	2	5
86	4	4	5	4	4	5	4	4	4	4	4	4	4	4
87	5	5	4	5	4	4	5	5	5	5	5	5	4	5
88	5	5	4	5	5	5	5	5	5	5	5	5	1	5
89	4	4	2	4	5	4	4	3	3	4	4	2	3	4
90	4	4	2	5	5	5	5	3	5	5	5	4	3	5
91	5	5	1	5	1	1	5	5	5	5	5	5	1	5
92	4	4	2	4	2	2	4	4	4	4	4	4	2	4
93	4	2	2	3	2	4	3	1	4	4	4	2	4	4
94	3	3	2	4	4	5	4	4	5	4	5	5	1	5
95	5	5	1	5	1	1	5	4	3	3	1	3	3	2
96	5	5	1	5	1	5	5	5	5	5	5	5	4	5
97	4	4	3	3	1	3	3	2	4	4	5	4	4	4
98	4	4	3	4	2	4	4	4	4	4	4	4	3	4
99	3	3	2	3	2	3	3	3	4	4	4	3	4	3
100	4	4	4	4	5	5	4	4	3	4	4	4	4	4

Respondent ID	Q1.1	Q1.2	Q1.3	Q2.1	Q2.2	Q2.3	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q6
101	4	3	2	2	2	3	4	4	2	2	4	4	3	2
102	3	3	1	2	2	2	3	3	2	3	4	3	3	4
103	5	5	5	5	5	5	5	5	5	5	5	5	5	5
104	4	5	2	5	3	4	4	3	4	3	4	3	3	5
105	5	4	3	4	4	4	4	3	4	4	5	5	4	4
106	4	4	4	4	5	5	4	3	4	4	4	3	4	4
107	5	5	5	5	5	5	5	5	5	5	5	5	4	5
108	5	5	1	5	1	1	5	5	5	5	5	5	1	5

Notes: Responses were recorded on a 5-point Likert scale (1 = lowest satisfaction/highest negative frequency; 5 = highest satisfaction/lowest negative frequency). For the adverse-condition frequency items (Q1.3, Q2.2, Q2.3, and Q5.3), responses were coded from 1 (very frequent) to 5 (never), such that higher scores represented more favorable evaluations; no additional reverse-coding was applied during statistical analysis.

S3. Indoor Environmental Measurements: Raw Data

Table S2: Room-averaged indoor environmental measurements in MUST Block R.

Measurement ID	CO_2 (ppm)			HCHO(mg/m³)			TVOC(mg/m³)			PM_{10}(μg/m³)			Noise (dB(A))			Temperature (°C)		
	R505	R319	R742	R505	R319	R742	R505	R319	R742	R505	R319	R742	R505	R319	R742	R505	R319	R742
Government reference	⩽1,000 [a]			⩽0.08 [a]			⩽0.60 [a]			⩽150 [a]			46 [b]			22–28 [a]		
1	884	884	610	0.005	0.005	0.005	0.003	0.002	0.004	16	25	22	47.9	51.7	51.8	23	25.2	24.8
2	878	871	602	0.007	0.003	0.005	0.008	0.001	0.006	20	22	19	48.2	51.2	52.4	23.3	25.2	25.1
3	874	803	612	0.008	0.007	0.002	0.005	0.001	0.005	16	31	22	47.8	52.2	52.5	23.5	25.2	25.2
4	814	882	627	0.005	0.004	0.001	0.002	0.001	0.003	17	22	14	51	51.9	52	23.7	25.2	25.1
5	712	880	625	0.007	0.005	0.003	0.007	0.004	0.004	21	23	32	49.2	52.3	51.3	23.9	25.2	25
6	737	810	638	0.003	0.004	0.005	0.002	0.002	0.006	25	14	28	46.9	51.8	50.7	24	25.2	25.4
7	652	843	653	0.003	0.003	0.003	0.004	0.001	0.007	25	19	16	46.5	52.9	50.9	24.1	25.2	25.4
8	676	897	664	0.005	0.003	0.002	0.007	0.005	0.007	24	27	18	47.4	54.6	50.3	24.2	25.3	25.4
9	634	875	671	0.003	0.005	0.003	0.003	0.004	0.005	22	27	31	47.9	55.1	50.6	24.2	25.2	25.4
10	644	860	680	0.005	0.004	0.001	0.003	0.004	0.006	12	32	26	48.3	55.1	50.1	24.2	25.2	25.4
11	608	869	651	0.005	0.004	0.005	0.004	0.006	0.005	24	22	25	48.6	55.7	50.4	24.2	25.2	25.5
12	636	894	636	0.007	0.007	0.002	0.008	0.007	0.006	12	21	15	47.9	55	50.9	24.2	25.2	25.5
13	661	843	636	0.006	0.007	0.001	0.005	0.006	0.004	25	25	24	49.8	54.7	51.2	24.2	25.2	25
14	565	846	627	0.006	0.003	0.002	0.006	0.004	0.007	20	18	24	47.6	55.9	51.1	24.2	25.2	24.7
15	656	872	631	0.006	0.006	0.005	0.005	0.007	0.005	18	31	15	46.6	55.9	51.3	24.2	25.3	24.7
16	639	839	627	0.004	0.004	0.005	0.006	0.002	0.004	23	24	23	47.7	55.7	51.5	24.1	25.2	24.6
17	591	888	625	0.007	0.007	0.004	0.004	0.001	0.008	12	24	22	47.9	55.8	51.8	24.1	25.3	24.6
18	669	874	642	0.007	0.006	0.005	0.006	0.005	0.005	20	31	32	47.2	55.3	51.2	24.1	25.3	24.6
19	821	880	652	0.006	0.005	0.004	0.006	0.002	0.003	19	26	32	46.8	57.2	50	24.1	25.3	24.6
20	573	837	670	0.006	0.005	0.002	0.004	0.005	0.005	13	17	27	46.3	56.2	49.8	24.1	25.3	24.8
21	562	890	669	0.006	0.004	0.001	0.002	0.006	0.005	16	25	29	46.7	56.8	49.3	24.1	25.3	24.8

[a] Source: DSPA (2014), Macao Guidelines for Indoor Air Quality in General Public Places, Table 2. Values are 8-hour averages; CO_2 ⩽0.1% and PM_{10} ⩽0.15 mg/m³ are converted to the units above. The measurements in this table support contextual comparison, not a determination of 8-hour compliance.

[b] Source: Chief Executive Dispatch No. 96/2020, Acoustic Regulation, Section 3.4.3. The Taipa daytime indoor background reference is 56 − 10 = 46 dB(A), applicable when background noise cannot be measured because of technical difficulties. It is not an occupied-classroom noise limit.

Note: Each reported value is the arithmetic mean across three measurement points for one monitoring interval. The 21 records per classroom are successive room-averaged observations from one session, not independent classroom replicates. R505, R319, and R742 were monitored on different dates.

S4. Lighting Performance Simulation of a Representative Classroom

To complement the visual-environment assessment presented in Section 3.6, a DIALux evo simulation was performed to characterize the artificial-lighting performance of a representative classroom model based on the standard geometry and installed lighting configuration shared by the three monitored classrooms (R319, R505, and R742). During the classroom investigations, curtains were observed to remain closed for much of the teaching time to facilitate projection. Accordingly, the simulation was restricted to artificial lighting without daylight contributions, and illuminance was evaluated on a horizontal working plane positioned 0.750 m above floor level.

S4.1 Room and Luminaire Parameters

The representative lighting model was developed using the standard geometry and installed lighting configuration shared by the three monitored classrooms (R319, R505, and R742), which have the same classroom dimensions and lighting arrangement. The model had a floor area of 141.12 m² (16.800 m × 8.400 m) and a ceiling/luminaire installation height of 3.250 m. Room surface reflectances were set to 70% for the ceiling, 50% for the walls, and 20% for the floor, and a maintenance factor of 0.80 was applied. The artificial-lighting system comprised 36 LEDVANCE PanelLED Value 600 luminaires (40 W and 3,600 lm per luminaire), arranged in a 9 × 4 ceiling grid, consistent with the representative lighting configuration of the investigated classrooms. Total installed power was 1,440 W and total luminous flux was 129,600 lm, corresponding to a lighting power density of 10.20 W/m². The working plane was set at 0.750 m above the floor with a 0.500 m border zone. The room-use profile was set to “General Classrooms, Learning/teaching, Hardcopy and writing” for simulation purposes, while interpretation used the 500-lx local classroom reference in Macau. Only artificial lighting was considered in the simulation. The main simulation parameters are summarized in Table S3.

Table S3: Summary of artificial lighting simulation parameters.

Parameter	Value
Room area	141.12 m²
Room dimensions	16.800 m × 8.400 m
Installation / ceiling height	3.250 m
Calculation plane height	0.750 m
Ceiling reflectance	70%
Wall reflectance	50%
Floor reflectance	20%
Maintenance factor	0.80
Luminaire model	LEDVANCE PanelLED Value 600, 40W / 6,500K
Luminaire quantity	36
Power per luminaire	40 W
Luminous flux per luminaire	3,600 lm
Color temperature	6,500 K
CRI	≥ 80
Total installed power	1,440 W
Total luminous flux	129,600 lm
Lighting power density	10.20 W/m²

S4.2 Simulation Results

The calculated illuminance results for the working plane (WP1) are summarized in Table S4. The average illuminance ($\bar{E}$) was 668 lx, the minimum illuminance (E_{min}) was 441 lx, and the maximum illuminance (E_{max}) was 757 lx. The overall illuminance uniformity ($U_0 = E_{min}/\bar{E}$) was 0.66, the mean-to-minimum illuminance ratio ($\bar{E}/E_{min}$) was 1.51, and the minimum-to-maximum illuminance ratio ($g_2 = E_{min}/E_{max}$) was 0.58. The maximum Unified Glare Rating (UGR) was 22, exceeding the classroom reference limit of 19 adopted for comparison. This reference is specified for classrooms in the SLL Code for Lighting 2012 and is referenced by BEAM Plus for artificial-lighting assessment. Estimated annual lighting energy consumption was 1,915 kWh/a. This annual figure is a simulation estimate, not measured electricity consumption.

Table S4: Illuminance results for the horizontal working plane (WP1; height: 0.750 m; edge zone: 0.500 m).

Parameter	Value	Standard / Reference
Average illuminance ($\bar{E}$)	668 lx	≥500 lx (Macau classroom reference)
Minimum illuminance (E_{min})	441 lx	—
Maximum illuminance (E_{max})	757 lx	—
Uniformity ($U_0 = E_{min}/\bar{E}$)	0.66	—
Minimum-to-maximum ratio ($g_2 = E_{min}/E_{max}$)	0.58	—
Unified Glare Rating (UGR_{max})	22	≤19 (SLL classroom reference)
Estimated annual energy consumption	1,915 kWh/a	—
Lighting power density (**LPD**)	10.20 W/m²	—

Figure S1 presents the luminaire layout and working-plane illuminance distribution generated by the DIALux simulation.

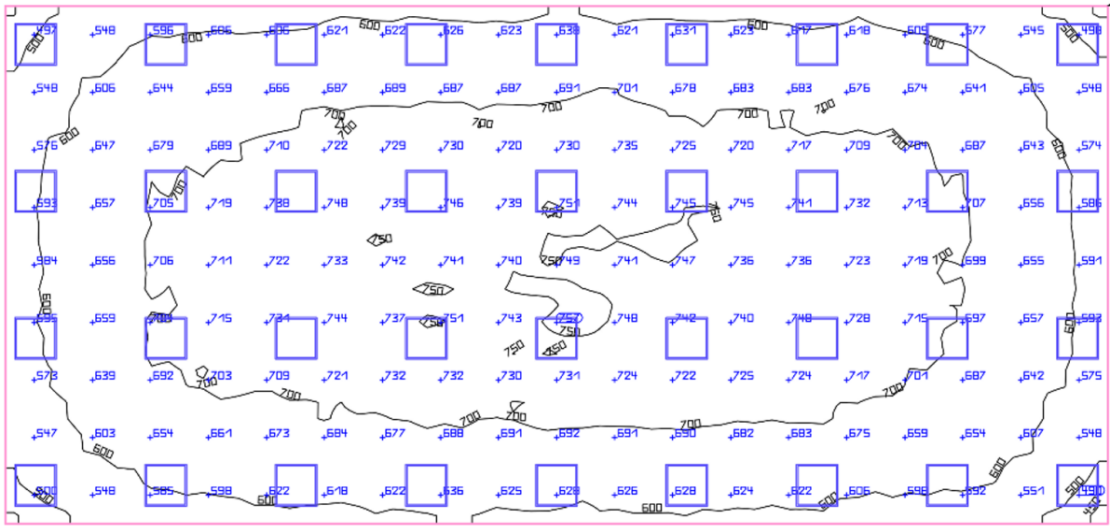


Figure S1: Luminaire position layout and working-plane illuminance distribution for a representative classroom model, as generated by DIALux simulation. The calculation plane height is 0.750 m. Average illuminance: 668 lx; minimum: 441 lx; maximum: 757 lx; uniformity U_0: 0.66.