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Original

Indoor Air and Light Quality Assessment in a University Campus Classroom / Aliakbari, Farzaneh; TORABI MOGHADAM, Sara; Lombardi, Patrizia. - In: JOURNAL OF SUSTAINABLE ARCHITECTURE AND CIVIL ENGINEERING. - ISSN 2029-9990. - ELETTRONICO. - 1:30(2022), pp. 163-182. [10.5755/j01.sace.30.1.30328]

Availability:

This version is available at: 11583/2963233 since: 2022-07-08T16:34:58Z

Publisher:

Kaunas University of Technology

Published

DOI:10.5755/j01.sace.30.1.30328

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Abstract: Educational building performance should provide a secure, healthy, and comfortable indoor environment for students since they spend a noteworthy part of their time inside. This study aims to assess the indoor air and light quality of a campus classroom through the selection of a set of relevant indicators from an existing green rating tool, the WELL Building Standard (WBS). The research methodology consists of three main phases; indicator selection, impact assessment, and validation process. The engagement of stakeholders was taken into the account in the entire research framework. The research findings showed that there is a considerable gap among the acceptable range of indoor air and light quality of the classroom. This led to verify various health issues among the students, including dryness and irritation of the skin and eyes, and consequently increased their dissatisfaction rate. The study provides some significant insights based on the obtained results, highlighting the importance of incorporating student health and wellness into educational building design and operations, including visual comfort and indoor air quality conditions, which are often worse than the stipulations in standards.

Keywords: Educational building performance, Indoor air and light quality, WELL Building Standard (WBS), Health issues

1. Introduction

Studies on health and wellness of occupants have received much attention in recent years, especially in educational buildings. The health-centered approach regarding occupants is at the heart of these two Sustainable Development Goals(SDGs): 3 “Ensure healthy lives and promote well-being for all at all ages” and 4 “Ensure inclusively and quality education for all and promote lifelong learning opportunities for all” [1–3] [1,4].As stated by the National Institute for Occupational Safety and Health (NIOSH), Indoor Environmental Quality (IEQ) refers to the environmental quality of the buildings, in relation to the health and wellness of occupants [5–8]. The IEQ is determined by a range of environmental factors, such as thermal comfort, lighting, acoustic quality, and indoor air quality [6,7,9,10].

It is well accepted that indoor air and light quality issues have negative impacts on human health [11–13]. Particularly, students are considered more vulnerable to the poor IEQ since they spend a noteworthy part of their time in the scholastic environment [14–18]. In addition, classroom IEQ is crucial to early-life exposures that could increase the risk of disease across the lifespan [19,20]. Therefore, the educational buildings should provide a secure, healthy, and comfortable indoor environment for students [2]. More importantly, adequate IEQ in classrooms is meant to provide a productive, safe, and comfortable environment for students [24]. Thus, the indoor school environment needs specific attention [19]. This study is motivated by the main concern of poor IEQ in the campus buildings, which can lead to health issues, high virus transmission rates, and

reductions in learning performance in the long-term [14,25,26]. [18].[21] [14,26,27]. To date, many studies have investigated the IEQ influences on the health and wellness of students in educational buildings [21–23].

These studies have focused on the IEQ assessment concept in campuses and its relationship with the satisfaction level of students, employing different quantitative and qualitative methodologies (e.g., measurements, surveys) [14,21,22,28]. A recent study has introduced a ‘green’ building as a building that reduces the negative impacts on the environment during its lifecycle. Moreover, it focused on assessing green buildings through the Environmental Building Rating Systems [29]. Another study conducted a comprehensive literature review regarding the impact of IEQ on the health and wellbeing of occupants [30]. This study introduces Malaysia’s Green Building Index (GBI) and highlights the IEQ as a fundamental criterion of the green building rating system to be considered while designing, constructing, and operating a building (either residential or non-residential) [30]. Moreover, the evaluation of IEQ and student satisfaction levels regarding a campus building has been conducted by Mohd Amri Sulaiman et al. [31], based on four main IEQ parameters—thermal comfort, auroral comfort, indoor air quality, and lighting through on-site measurements and a questionnaire survey [31]. Similarly, another study has investigated the use of quantitative and qualitative methods (i.e., measurements of IEQ parameters and post-occupancy evaluation) to explore the performance level of the building and user satisfaction, according to the GBI [32].

As mentioned above, various studies have measured different IEQ parameters, such as temperature, and humidity, for their specific case study in order to assess the sustainability level of the building. In addition, they analyzed the satisfaction level of users of the place by utilizing questionnaire surveys.

However, none of the previous studies has selected key indicators relying on a green rating tool and measured the impact of IEQ parameters in relation to the students’ health. In other words, the previous studies have not specifically focused on the measured-based process and have not compared their indicators assessment results with the targets of a rating system and standard. The difference between the present study and the previous ones is that a specific performance-based tool and its relative indicators for IEQ parameters associated with student health were considered. Specifically, the selection of indicators that provides the opportunity to realistically measure the most important factors of IEQ in the campus building influencing student health and wellness is conducted.

At present, the green school concept is of great importance and efforts are being made to raise awareness of sustainable development [33,34]. In 2018, a comprehensive review on six green school rating systems which have been distributed worldwide was conducted [34]. These global rating systems were developed in various countries, including the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, Leadership in Energy and Environmental Design (LEED) in the United States, Foundation for

Environmental Education (FEE) for ECO-Schools in Europe, Green Star Education in Australia, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, and China Society for Urban Studies (CSUS) in China [34]. Moreover, the University of Indonesia (UI) Green Metric World University Ranking has been introduced as an international rating system to assess the situation of green campuses [35]. In 2016, the WELL Building Standard (WBS) for educational facilities in United States was launched, to work beside LEED and other global green systems, with the intent to monitor the features of the built environment and address issues related to human health [36,37]. WBS is a well-known green building assessment system that assesses educational sustainability performance and certifies health and wellbeing in the built environment [36,38]. WBS includes seven criteria: Air, Light, Nourishment, Water, Waste, Mind, Fitness, and Comfort [36].

All other existing sustainability and green rating tools differs in their structural features, such as the weighting schemes and the assessment ranking [39]. However, all those tools take into consideration the various environmental issues and intend to promote environmental health, as well as human health and wellbeing [34]. The present paper is the first attempt that explores the key indicators related to the light and air quality, which contribute to the health of students. In this research, the WBS was chosen due to its multidisciplinary performance and its suitability to deal with health and wellness aspects. The WBS assesses the IEQ on human health through the set of various indicators of air, light, and comfort. Particularly, the WBS indicators are based on a human-centered orientation approach [36,37].

Giving this background, the present research has raised the following question: *“What are the key indicators related to the light and air quality which contribute to the health of students? And how these indicators can be selected and assessed?”*

2. Methodological framework

The methodological framework proposed for this study consists of three major Phases: indicator selection (Phase I), impact assessment (Phase II), and validation process (Phase III).

The aim of **Phase I**, indicator selection, was to reduce the number of non-practical and inefficient indicators and maintaining those which are most adequate to perform a concrete IEQ assessment. Although a vast number of indicators exist for the assessment of IEQ performance, it is not absolutely helpful to have more and more indicators [40]. To the contrary, fewer indicators may sometimes be more advantageous for evaluating the relative issues. Generally, the selection of indicators requires consideration of those which are SMART; that is, Specific, Measurable, Achievable, Relevant, and Time-bound [41,42].

This phase was divided into three steps: pre-selection, filtration, and final selection. The procedure starts from the comprehensive review of WBS indicators to preselect them. Regarding the filtration process, stakeholders' opinions has been taken into account.

The IEQ assessment at the sustainable campus requires the comprehensive vision of different expertise in various sectors [43]. Hence, multiple stakeholders in the selection of indicators should be involved who can influence or will be influenced by the recognition of objectives [44]. To this end, this study first has performed the stakeholders' analysis employing the power-interest grid in order to identify the relevant experts in light and air sectors. Afterward, a specific questionnaire was designed to select the most important indicators according to the stakeholders' opinions. The questionnaire proposed a voting scale for the experts in relation to their preferred indicators. In the questionnaire, the authors avoided expressing any personal preferences and played only the role of analysts [45]. At this stage, in order to select the final set of indicators, the availability of data was taken into account since they should be measurable, achievable, straightforward and cost-effective [41].

In **Phase II**, the impact of the selected indicators was assessed. The impact assessment procedure was performed based on the literature review, technical documents investigation, focus groups with stakeholders, data measurements, elaboration of geometric data, and in-situ analysis [46].

The purpose was to measure the indicators in a quantitative and qualitative ways to verify if they meet the targets defined by WBS. According to the WBS if the evaluated indicators do not meet those targets, various health issues among the users might happen [36].

Into this, in **Phase III** (validation process) a further survey has been launched to validate the primary research findings from the phase II. The survey intends to engage the students to verify which health issues are common among the students during their presence at the location considering their perceptions. Moreover, their satisfaction level is evaluated through the questionnaire. Furthermore, the study involved the specialized doctors to verify the stated health issues by the students and identify the factors that effect on their health. This is because it should consider the specialized doctors' assessments rather than only the students' responses to a questionnaire.

Table 1 illustrates the schematic overview of the research methodology, as described above.

Table 1. Research methodology overview.

Phases	Steps	Methods	Outputs
I. Indicator selection	Pre-selection	Protocol review	Consider all WBS indicators
	Filtration	Stakeholders' analysis employing the power-interest grid	Select the most important indicators according to the stakeholders' opinions
		Launch of questionnaire	

	Final selection	Data analysis	Select those indicators where the data is available and measurable
II. Impact assessment	Data collection	Literature review	Measure the value of each indicator if they meet the targets defined by WBS
		Technical documents investigation	
		Focus groups with stakeholders	
		data measurements	
		Elaboration of geometric data	
		In-situ analysis	
III- Validation process	Students' survey and specialized doctors' engagement	Questionnaire and Diagnosis	Involve the specialized doctors to verify the stated health issues by the students and identify the factors that effect on their health
			Verify the health issues among students and satisfaction level during their presence hours

2.1. Case study

The Polytechnic University of Turin (Polito) is located in the city of Turin in Italy, and it has a continental temperate climate. A large size classroom, "classroom 1", located at the main campus of the Polito, built in 1958, was chosen as a case study to implement and test the proposed methodology. The classroom area is about 318.11 m² and its volume is almost 1460 m³ possessing 408 seats. The air conditioning of the classroom is supplied by an Air Handling Unit (AHU) [47]. The Heating, ventilation, and air conditioning (HVAC) system of the classroom consists of a compressor, a condenser, an expansion valve, and an evaporator. HVAC systems follow a thermodynamic process to remove heat from one place, replace it with cold air, and expel the hot air to the outside atmosphere [48]. They take the most power consumption to carry out the indoor environmental comfort [49]. The classroom HVAC system has been working since 1991 and the

operation hours are 8:00 am to 7:00 pm from Monday to Friday and from 8:00 am to 2:00 pm on Saturday. The commercial building management system for HVAC (Desigo™) developed by Siemens is the basis of the control system for the classroom [47]. In the building renovation process in 2015, new automatic windows were installed. However, the window operations are not controlled by the Desigo™ software. The data related to the air quality (e.g., temperature, relative humidity, and CO₂) has been measured by the HVAC system of the classroom from 2011 up to now. Figure 1 shows an interior picture of the classroom.



Figure 1. Polito, Campus in Corso Duca degli Abruzzi, Classroom 1.

Source: Photo by Polito Data Lab, October 2019.

3. Results and discussion

This section reports the results of each phase, and it discusses the significance of findings. The outcomes obtained from the application of the methodology in the case study (classroom 1) are outlined below;

3.1. Phase I— Indicator selection

The pre-selection started from 94 indicators, which were the total indicators of WBS classified into seven categories: Air, Water, Nourishment, Light, Fitness, Comfort, and Mind. As the case study was a classroom which is an interior part of the building, the indicators that did not have any impact on IEQ were discarded, i.e., Water, Nourishment, Mind and Fitness. At this point, the number of indicators was reduced to 50.

The filtration started with the design of the specific online questionnaire to select the final set of indicators. Initially, the stakeholders were identified among academic experts in the field of energy and through the interests-power grid were mapped. Afterward, the online questionnaire was launched among those 80 selected stakeholders.

The goal of the voting process was to identify the most significant indicators relative to the indoor air and light quality of the classroom, which can affect the health of students. By considering the opinion of all the experts in the field, it was possible to carry out a pre-selection of indicators and rate the importance of the different issues for IEQ assessment.

The experts were asked to answer the questions based on an ordinal scale of 0 to 4 (0 = not important to 4 = very important and DK (Does not know)), in order to express their preferences. In particular, the experts rated each indicator according to three main criteria—(i) understandability, (ii) measurability, and (iii) relevancy.

Based on the experts' answers, the indicators were first ranked from the most preferred to the less ones. Then, formula (1) was employed to select the limited number of indicators [50]. The average rate (X) of indicators was calculated by summing the total rates of all indicators (Q) and dividing it to the total number of indicators (Z). By this method, the indicators which had the total rate (Y) more than the average rate (X) in each category were selected.

$$Q/Z = X \quad \text{if} \quad Y \geq X \rightarrow \text{Select the indicator} \quad (1)$$

The results of the questionnaire highlighted the 12 most important indicators categorized into Comfort, Air, and Light. In fact, they highly voted those indicators that affected the IEQ issues, in terms of student health and, hence, the less important indicators were ranked at the bottom of the list.

The data availability and measurability were also considered to select the final set of indicators. In this phase, the comfort category was eliminated, as the data related to its indicators were not available to be assessed. Therefore, the final selection led to select 7 indicators. The data related to the selected indicators were collected from the existing databases (i.e., Data lab and Building Area) of the Polito campus. [Table 2](#) shows the list of the final seven indicators and explain about their objective and unit.

Table 2. Final set of indicators, source WBS [36]

Category	Code	Indicator	Objective	Unit
Air	A1	Humidity Control; Relative Humidity	To provide adequate humidity levels by limiting the growth of pathogens, reducing exhaust gases, and preserving thermal comfort.	%
	A2	Smoking ban; Indoor smoking ban	To avoid smoking, reduce air pollution, and decrease the exposure of non-smokers to smoke.	_
	A3	Air filtration; Particle filtration	To eliminate indoor and outdoor air pollution through air filtration.	%

Light	L1	Daylighting fenestration; Window sizes for working and learning spaces	To reduce excessive radiation and make the exposure of the occupants to daylight better by increasing fenestration parameters.	%
	L2	Daylighting fenestration; Window Transmittance in Working and Learning Areas	To reduce excessive radiation and make the exposure of the occupant to daylight better by increasing fenestration parameters.	nm
	L3	Right to light; Window access for working & learning spaces	To increase occupant exposure to daylight and increase outside view by reducing the distance of workstations or desks to a window or atrium.	m
	L4	Solar glare control; Daylight management	To avoid sun glare by obstructing or mirroring direct sunlight from occupants.	_

3.2. Phase II— Impact assessment

Within Phase II, the impact of the final seven selected indicators were assessed for the classroom 1 to explore the indoor air and light quality, and consequently, their impact on student health. Table 3 summarizes how each indicator was evaluated illustrating the assessment methods (the description of how the indicator can be measured), type (quantitative vs. qualitative), and data sources (a list of resources that were used in developing the indicators assessment).

Table 3. Summarization of overall assessment of indicators, source [36,51–53].

Code	Unit	Assessment method	Type	Data source
A1	%	Calculations/ Measurement	Quantitative	Data measured by Data Lab at Polito campus

A2	–	Policy Document/Visual inspection	Qualitative	Literature Review
A3	%	Calculations/Measurement	Quantitative	Regional Agency for Environmental Protection (ARPA) Piemonte, Italy
L1	%	Architectural Drawing/ Visual Inspection	Quantitative/Qualitative	Architectural drawing documents created by Building Area at Polito Campus
L2	nm	Architectural Drawing/Architect	Qualitative	Technical office at Polito Campus
L3	m	Architectural Drawing/ Visual Inspection	Quantitative/Qualitative	Architectural drawing documents created by Building Area at Polito Campus
L4	–	Architectural Drawing/ Visual Inspection	Quantitative/Qualitative	Architectural drawing documents created by Building Area at Polito Campus

The upcoming part is dedicated to the assessment of indicators, which was thoroughly examined in the case study. In this part the WBS requirements for each indicator, their assessment procedure, and evaluation results are fully described.

- **Indicator A1. Humidity Control; Relative Humidity (RH)**

Requirements of WBS:

According to WBS, at least one of the following is required:

- An air conditioning system capable of maintaining the relative humidity between 30% and 50% during all presence hours, by reducing or increasing the humidity to the air.
- The humidity level modeled in the location for at least 95% of all the working hours of the year is within 30–50%. Buildings that are in humid areas are recommended to follow this feature [36].

Assessment process:

This indicator was assessed through specific measurements obtained from different networks of probes, sensors, data logs, and software. The data acquisition was achieved, at a time resolution of 15 minutes, for the whole year of 2019. The data was collected by the Living Lab of the Polito campus, written partly in the Perl script and partly in the R language, and was based on a Microsoft

Sql Server database for long-term storage. The data points related to every minute were exported into a text document and, after that, were imported into an MS SQL Server 2012 relational database and aggregated to a 15-minute basis. Figure 2 indicates the arrangement of RH, Temperature (T) values, and their correlation in 2019.

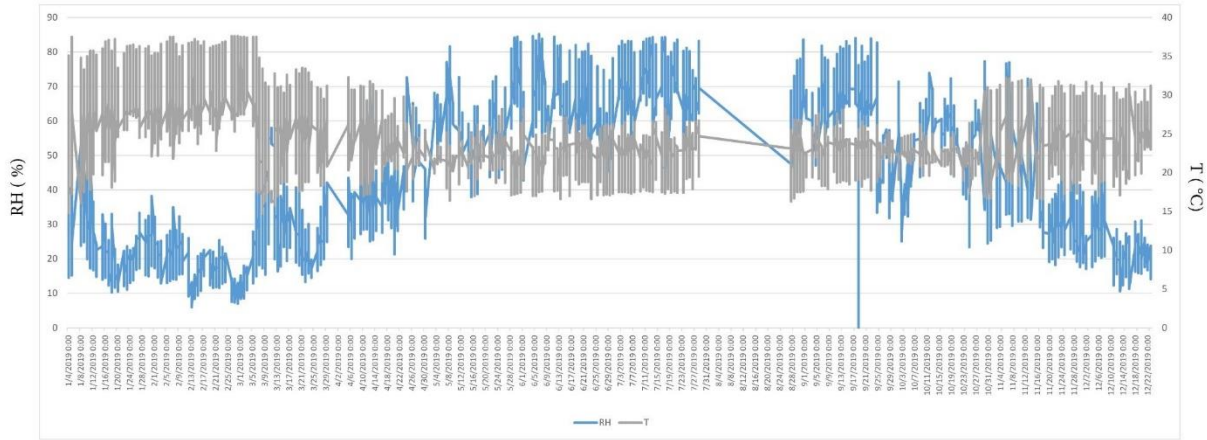


Figure 2. RH and T measurements at classroom 1 for 2019, source: Living Lab Polito.

According to Figure 2, the trend of changes in RH values experienced an enormous escalation from June/July/August to February/March. Looking at more details, RH began at 85 % on 9/6/2019, which was the highest humidity in 2019. Despite the highest value in June, the amount of RH then declined significantly and fell to the lowest rates of 10 % and 0 % on the 13th, and 20th of January and 13th of September, respectively. Considering the measurements, of 11,845 RH base detections every 15 minutes, only 2833 RH detected points were within 30–50% during presence times in the year 2019 (8:00 am to 7:00 pm from Monday to Friday; 8:00 am to 2:00 pm on Saturday).

In addition to the RH, the air temperature was also measured by the HVAC system. Despite having reached a peak of 35 °C in January/February 2019, the changes in the Temperature value had a period of stability from May to October (with an average of 23°C). What stands out in Figure 2 is that the trend then escalated slowly from October to December 2019.

The figure also illustrates the correlation between the changes of T and RH amount in 2019. With respect to the information given by the graph, the humidity values experienced a significant rise in RH from March to May 2019 with a peak of 83 % on 8/5/2019, while the Temperature showed an enormous decline during that period and remained stable from 4/5/2019 to 31/10/2019. The RH then saw a significant reduction and fell to 7 % on 22/12/2019. Despite fluctuating heavily between 4/1/2019 and 18/4/2019, the trend of T changed, then remained steady at 50 %.

To conclude, the T values were quite stable during the period and did not change with high fluctuations, while the RH values changed rapidly. The reason for this is that the Air Handling Unit (AHU) of the classroom measures the RH without controlling it, and the ventilation system

of the classroom is obsolete; whereas the temperature of the classroom is controlled by the HVAC system and the above measurement confirm the stable variations in the T values.

Evaluation result:

According to the measurements, not all of the RH values were in the required range (30–50%), and only a few days and hours matched with the WBS requirements.

• **Indicator A2. Smoking ban; Indoor smoking ban**

Requirements of WBS:

The following building policy is required:

- a. Smoking and e-cigarettes are prohibited indoors [36].

Assessment process:

Since 10 January 2005, the anti-smoking law banned smoking in all public indoor spaces in Italy [51–53]. Awareness of the building policy and an in-situ visualization has outlined that smoking is forbidden inside the Polito campus building and classrooms.

Evaluation result:

The smoking ban indicator for the classroom 1 met the WBS requirements.

• **Indicator A3. Air filtration; Particle filtration**

Requirements of WBS:

At least one of the following requirements should be encountered in the buildings:

- a. The filters with MERV13 (or higher) are used in the air conditioning system to filter outdoor air.
- b. The PM_{10} and $PM_{2.5}$ levels of the outdoor air measured within 1.6 km of the building for 95% of yearly hours are less than the limits indicated in the WELL Air Quality Standards feature [36].

Assessment process:

This indicator was assessed by an energy simulation software, which checks all the filters located in the ventilation system of the classroom to determine the Minimum Efficiency Rate Value (MERV). The calculation process was carried out considering the particle size range [nm], Average minimum Particle Size Efficiency (PSE) designator (

%), and fractional efficiency (%). [Table 4](#) demonstrates the results of the fractional efficiency MERV calculations for the filters.

Table 4. Fractional Efficiency MERV calculations

Particle range[nm]		size	Fine filter #1	Fine filter #2	Fine filters #3 & #4				
Lower limit	Upper limit	Geometric mean	Fractal efficiency [%]	Average minimum PSE [%]	Fractal efficiency [%]	Average minimum PSE designator [%]	Fractal efficiency [%]	Average PSE designator [%]	minimum designator [%]
300	400	346.41	78.73	87.85	80.25	89	78.18	87.06	
400	550	469.04	86.36		87.72		85.79		
550	700	620.48	90.89		92.49		90.51		
700	1000	836.66	95.46		95.54		93.75		
1000	1300	1140.18	99.68	97.69	97.18	98.22	96.43	97.10	
1300	1600	1442.22	99.62		97.83		96.42		
1600	2200	1876.17	98.32		98.72		97.18		
2200	3000	2569.05	99.40		99.13		98.35		
3000	4000	3464.10	99.60	99.83	99.30	99.60	98.60	99.20	
4000	5500	4690.42	99.80		99.50		99.00		
5500	7000	6204.84	99.90		99.70		99.40		
7000	10000	8366.60	100		99.90		99.80		

Minimum Reporting (MERV)	Efficiency Value	MERV 15	MERV 15	MERV 15
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Evaluation result:

From the measurements, it was outlined that all the filters placed inside the AHU of the classroom correspond to MERV 15 and the filtration system was better than the minimum required.

• **Indicator LI. Daylighting fenestration; Window sizes for working and learning spaces**

Requirements of WBS:

The following conditions should be observed in facades with regularly occupied spaces:

- a. On the external facades, the window–wall ratio should be between 20% and 60%. If the ratio is over 40%, it requires exterior shading or tunable glazing, which are able to control unwanted heat gain and glare.
- b. If the ratio is between 40% and 60%, the windows should be located at least 2.1 m above the floor [36].

Assessment process:

This indicator was assessed in three steps. In the first step, architectural drawings (DWGs) of the classroom (e.g., section, plan, and view) were utilized to measure the window and wall areas. The window–wall ratio calculations followed Formula (2):

$$(Windows\ area/walls\ area) \times 100\ \% = Ratio, \tag{2}$$

If $\sum Ratio > 40\%$ → windows need external shadings.

The classroom had a total of three exterior walls (2 walls A + 1 wall B) and 13 windows which varied in size (5 windows on each wall A + 3 windows on wall B). The results of the measurements were as follows:

$$Wall\ A: (Windows\ area/Walls\ area) \times 100\%,$$

$$[(208 \times 150) + (224 \times 150) + (240 \times 150) + (257 \times 150) + (270 \times 150)] \div 13166.28 = 13\%$$

$$Wall\ B: (Windows\ area/Walls\ area) \times 100\%,$$

$$[(240 \times 165) + (240 \times 165) + (283 \times 165)] \div 646697 = 19\%,$$

$$\sum \text{Ratio} = (2 \text{ Ratio wall A}) + \text{Ratio wall B},$$

$$(2 \times 13\%) + 19\% = 45\%.$$

According to these calculations, the total window–wall ratio was about 45%. In the second step, the distances of walls and windows were measured, using the DWGs. The measurements outlined that all the windows were located 3.5 m above the floor. At the third step, an in-situ survey was implemented, which confirmed the presence of exterior blinds attached to the windows of the classroom. [Figure 1](#) shows an interior picture of the classroom, with the exterior blinds on the windows.

Evaluation result:

According to the measurements, the window–wall ratio in the classroom 1 was more than 40% and the distance of windows from the floor is more than 2.1 m. Moreover, the windows had the exterior shadings, and the indicator fulfilled the WBS target.

• ***Indicator L2. Daylighting fenestration; Window Transmittance in Working and Learning Areas***

Requirements of WBS:

The following Visible Transmission (VT) conditions should be met for all non-decorative glazing:

- a. All glazing located 2.1 m above the floor should have a VT of 60% or more.
- b. All glazing (excluding skylights) located equal to or less than 2.1 m from the floor should have a VT of 50% or more [36].

Assessment process:

To assess this indicator, the distances between all windows and the floor were measured using the architectural drawings, and it was determined that all the windows were located 3.5 m above the floor. Moreover, the technical office of the Polito campus (the relevant experts) confirmed that all the glazing used in the campus building had a Visible Transmission (VT) of 60%.

Evaluation result:

The indicator met the WBS requirements regarding the glazing VT conditions.

• ***Indicator L3. Right to light; Window access for working and learning spaces***

Requirements of WBS:

The following conditions should be met in the buildings:

- a. The distance between 75% of workstations or desks from an atrium or a window which have the possibility to see the outside should be 7.5 m.
- b. The distance between 95% of all workstations from an atrium or a window which have the possibility to see the outside should be 12.5 m [36].

Assessment process:

This indicator was assessed using architectural drawings (DWGs) of the classroom to measure the distance between student's chairs and desks from the windows. The measurements showed that 84% of desks had a 7.5 m distance from windows without views to the exterior, as the windows of the classroom were located 3.5 m above the floor and students were unable to see the outside. Figure 1 shows the location of windows in the classroom.

Evaluation result:

The indicator did not meet the WBS requirements since the windows only had the function of providing light, and there was no visual view to the outside.

• ***Indicator I4. Solar glare control; Daylight management***

Requirements of WBS:

In regularly occupied spaces (excluding lobbies), if the distance between all the glazing and the floor is more than 2.1 m, at least one of the following is required:

- a. Automatic or manually controllable interior window shading, or blinds preventing excessive radiation.
- b. Automatic exterior shading systems to block excessive sunlight.
- c. Interior light shelves to reflect sunlight onto the ceiling.
- d. A window glazing system with micro-mirror film that reflects sunlight upwards.
- e. A variable transparency glazing, such as electrochromic glass, which can decrease the light and heat transfer by 90% or more [36].

Indicator assessment:

To assess this indicator, an onsite visualization of the classroom was implemented. In addition, the distances between windows and floors were measured, utilizing the architectural drawings (DWGs) of the classroom. The DWGs measurements indicated that windows were located 3.5 m above the floor. Furthermore, an onsite survey outlined the interior blinds attached to the glazing. The blinds were controllable through an electrical component. Figure 1 shows the presence of interior blinds on the windows.

Evaluation result:

The indicator met the WBS target since the presence of blinds which were controllable through an electrical component which manually control the excessive radiation.

Table 6 summarizes the WBS requirements and the results of the impact assessment. Over the seven indicators, five (A2, A3, L1, L2, and L4) totally met the requirements of the WBS, while the indicators A1 and L3 did not.

Table 6. Data verification results for indicators

Category	Indicator Code	WBS requirement [36]	Data Verified
Air	A1	The RH was between 30- 50% at all presence hours	×
	A2	Indoor smoking was forbidden in the classroom	✓
	A3	Filters had MERV 13 or higher	✓
Light	L1	If window–wall ratio was between 40-60%, the external shadings was required	✓
	L2	All glazing has VT more than 60%	✓
	L3	The distance between 75% of students’ desks from a window which had the possibility to see the outside was 7.5 m	×
	L4	The distance between all the glazing and the floor was more than 2.1 m and the windows had blinds	✓

The results obtained from the impact assessment of indicator A1 showed that the ventilation system was not working appropriately. Moreover, the RH level was not between 30–50% in all of the presence hours. According to the WBS, a low level of humidity may cause health symptoms, such as skin dryness and irritation of the skin, eyes, throat, and mucous membranes. However, a high humidity level can lead to respiratory symptoms, especially in sensitive persons [36]. Regarding indicators A2 and A3, no incompatible situation was observed in the evaluation process. As indicated previously, smoking was forbidden in the entire campus and the filtration system was in a good condition. Therefore, they will probably not cause any health issues among the students relying on the WBS target. Moreover, the window sizes and, consequently, the window–wall ratio (indicator L1) and their transmittance rate (indicator L2) were in the acceptable range. Regarding indicator L3, the location of windows 3.5 m above the floor (and, thus, obviously above the heads of students) led to a lack of view to the exterior. As indicated in the WBS, having no views to the

outside may cause some psychological issues for students, such as depression and distraction during the time [29,36]. In contrast with this issue, all the windows had exterior and interior blinds (indicator L4), which were able to control the unwanted heat and light gain to the classroom. Thus, this may not cause exhaustion and discomfort among students.

The primary research achievements and comparison them with WBS needed to be validated and verified whether the indicated health issues were really felt by students. Into this, Phase III, as a validation process was designed.

3.3. Phase III—Validation process

A second online survey was launched, with the aim of verifying the results obtained in phase II to validate the primary research findings, regarding the health symptoms experienced by students. This survey was designed in order to compare the health issues indicated by the WBS and the real symptoms felt by students.

As anticipated, the health issues indicated by the WBS due to poor air and light quality of the classroom were dryness and irritation of the skin and/or eyes, throat, mucous membranes, respiratory irritation and allergies, depression, and distraction.

To this end, the questionnaire comprised four main close-ended questions , starting with a general question asking their gender as a socio- demographic variable (Q1) [54]. The main body of the questionnaire was designed according to consider the health of students. Q2 was related to the health symptoms due to the poor air quality of the classroom, while Q3 asked for details of the problems caused by poor light quality. In addition, Q4 evaluated the general health and satisfaction rate of the students of the classroom [55]. Moreover, an open-ended question, Q5, was added, which asked whether the students have any suggestions for the future improvements of indoor air and light quality of the classroom. The questionnaire is shown in Table 7.

Table 7. Student health questionnaire.

Dear students,

This questionnaire was designed to evaluate your health and satisfaction rate about the indoor air and light quality of the classroom 1 at main campus during your presence. Please answer to the following questions considering your real feelings and perceptions.

Questions	Responses		
1. Please indicate your gender?	Female	Male	Prefer not to say

2. Did you have any of the following health symptoms in the past 6 months?	Noticeable	Unnoticeable	Rarely noticeable	
Dryness and irritation of the skin or/and eyes				
Throat				
Mucous membranes				
Respiratory irritation and allergies				
3. Did you have any of the following psychological and neurological disorders in the past 6 months?	Noticeable	Unnoticeable	Rarely noticeable	
Depression				
Distraction				
4. Are you satisfied with	Very dissatisfied	Dissatisfied	Satisfied	Very satisfied
Lighting in the classroom?				
Ventilation system of the classroom?				
Please indicate your motivation...				
5. Do you have any suggestion for the future indoor air and light quality improvement of the campus? If yes, please write here.				

The questionnaire was launched in December 2019, the same year of the data collection. Even if the capacity of the classroom was 408 seats, during the research period (2019), only 120 students were present, and 91 students have filled in the online questionnaire. The precipitated students were composed of 35 males, 38 females, and 18 of them preferred not to say about their gender. Afterward, the data was accurately analyzed and elaborated. According to the questionnaire responses, some health symptoms were almost unnoticeable among the students in the classroom, such as mucous membranes and throat, with 88 and 78 unnoticeable responses, respectively, given by the students (see Figure 3). However, dryness and irritation of the skin and eyes were reported, with 60 noticeable responses. In addition, about 58 students felt depression and only 12 students

did not have any issue with distraction, while 42 of them were always distracted and 40 students were rarely distracted. Figure 3 shows the health symptoms of respondents, related to the indoor air and light quality of the classroom.

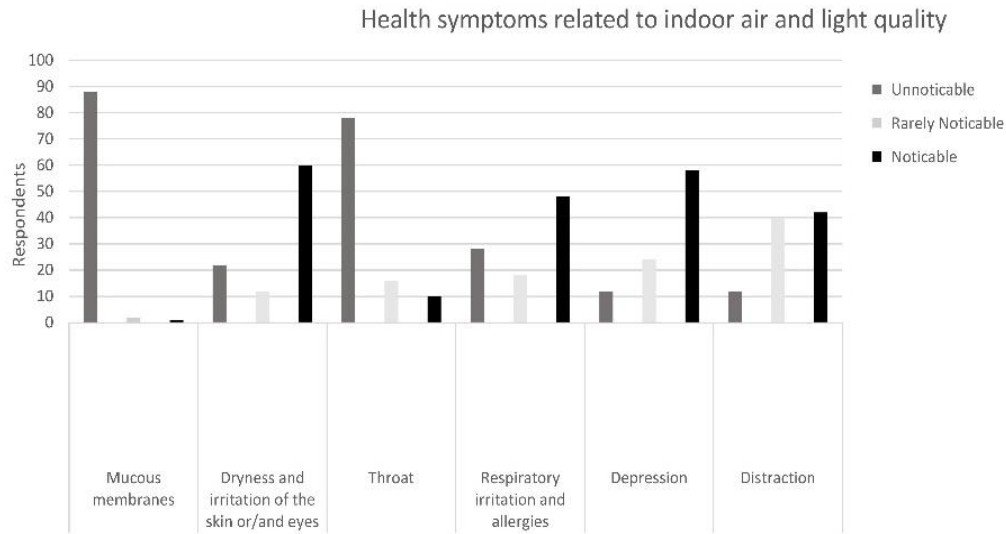


Figure 3. Health symptoms related to indoor air and light quality.

Based on 76 satisfied responses over 91, the feedback highlighted that almost all the students were satisfied with the lighting situation in the classroom, while they were not satisfied with the ventilation system (60 dissatisfaction responses). The high rate of satisfaction with the lighting system of classroom confirmed that it was in good condition, while only 24% of students were satisfied with the ventilation system, accounting for the least number of students. Figure 4 illustrates the satisfaction rate of students related to the indoor air and light quality of the classroom.

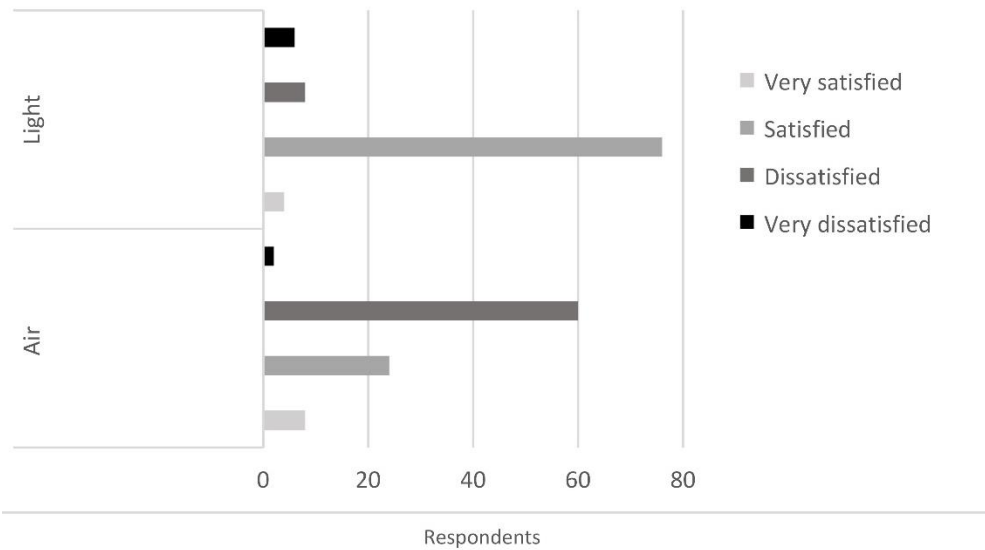


Figure 4. Satisfaction rate related to indoor air and light quality of the classroom.

Some of the students also provided their motivations for their dissatisfaction. They stated that “*the air seems very dense, and we cannot breathe well, the windows are never open*” and “*we would like a slightly brighter light, the air in the class does not seem fresh, It's too hot and humid*”.

Some students suggested to install better air conditioners and also air cleaning, which will be helpful for having fresh air in the classroom.

Notably, students' answers are often subjective and can be influenced by a plethora of external factors unrelated to the air and light issues. Moreover, due to the fact that the life and activity of students take place inside and outside the university campus, their health is also being influenced by external factors that must be taken into account. Hence, also the specialized doctors' assessments have been considered rather than only the students' responses to a questionnaire.

According to the analysis, the health symptoms felt by students, such as irritation and allergies, were due to inappropriate levels of RH in the classroom, as was seen in the impact assessment result for indicator A1. Besides, the lack of external and natural light caused depression and distraction among a major part of students, confirming the validity of the assessment results for Indicator L3.

4. Future Insights

After the impact assessment of the indoor air and light quality of the classroom, three significant insights are provided based on the key findings of the present study and interview with experts. By doing this, the present study intends to promote a high level of indoor air and light quality, in order to improve the health of students. The given insights take into account social, environmental,

and economic aspects with the aim of aiding designers to make better decisions in the design phases of the project by linking to the different SDGs, to better reflect the idea behind it.

- **Adapting the HVAC system of the classroom:** The design of HVAC systems is a challenging engineering task which requires experienced decision-making[56]. Moreover, the properties of HVAC systems are very important for health purposes, and their adaptation can help to reduce the risk of various infectious diseases which are transmittable by the ventilation system [57,58]. In fact, the indoor temperature and humidity are high in a building, the virus transmission reduces. However, it is important to change the indoor air with the fresh outdoor air [59–61]. The simulation results and relevant experts' advice demonstrated that the HVAC system of the classroom has no device to control the RH; thereby, the RH is not at an appropriate level at all during the presence hours. Considering the present case study, it is quite probable that the infection risk of viruses, such as the novel coronavirus causing COVID-19, could be increased during the presence time, due to the inappropriate ventilation rate and RH level, especially when the RH is low. Therefore, adapting the HVAC system of the classroom is a vital point to improve the indoor air quality and advance the health of students. (Link with SDGs 3, 4, 7, 13, 16, 11)
- **Using Photocatalytic oxidation technology in the central ventilation system:** Photocatalytic oxidation technology plays an important role in human health, by purifying the indoor air. This technology has been used in various places, such as buildings materials, ventilation systems, and furniture [62]. Therefore, according to the expert opinions, using this technology in the central ventilation system of the classroom may help to remediate indoor air pollution and help to decrease possible health issues among the students. (Link with SDGs 3, 4, 7, 11, 13)
- **Using active shading systems:** Active shading systems fall into three categories: Integrated renewable energy shading, kinetic shading, and smart glazing [63]. Dynamic shading systems minimize building energy consumption, balance IEQ, and improve occupant visual and thermal comfort [29,63]. These systems fold, slide, expand, shrink, and transform in the shading devices if exposed to mechanical, chemical, or electrical drivers [63]. In the studied classroom, the glazing shadings were not automatic, but are manually controllable by the students through an electrical component. Therefore, in the classroom, daylight could have undesirable side effects, such as unwanted heat gains and glare. In this regard, installing automatic shading devices and light sensors is vital to reduce excess heat gain and glare, thus improving the indoor light quality of the classroom, as well as student health. (Link with SDGs 3,4, 7,13)

5.. Conclusions

The present study addressed the need of the selection of the indicators from the green rating tool which assesses the indoor air and light quality of a campus classroom, which contributes significantly to the health of students. In this route, among various campus green rating tools, the

WBS was selected due to its suitability to deal with health and wellness aspects. The number of seven indicators was selected from WBS through protocol review, stakeholder analysis, and data analysis. The value of each indicator has been assessed to verify if they meet the WBS targets. Finally, the health issues among students and their satisfaction level during their presence hours have been analyzed employing specialized doctors. The authors point out some of the most relevant findings of the present study which cover three points:

It is crucial to engage the expert stakeholders in the process of the indicator's selection: in fact, engaging the stakeholders led to consider different technical aspects. Hence, a specific questionnaire was developed and filled out by relevant experts in the field, with the aim of selecting the most relevant indicators that mainly contribute to indoor air and light quality and, consequently, student health and wellness.

The indicators need to be measured by collecting a real data: after selecting the indicators, the necessary data was collected through the indicated methods showed in Table 2 to assess the impacts of indicators in the specific case study. It is notable to say that there is a need to preprocess the data in order to prepare an accurate, reusable, and elaborated information.

The social aspects such as student's perception should be integrated into the process: this study emphasized the importance of integrating the social aspects into the technical ones engaging the students. Into this, specific questionnaire has been distributed among the students, and consequently, their responses showed that two health symptoms were the most widespread; (i) dryness and irritation of the skin about 66%, and (ii) eye and respiratory irritation and allergies about 52 %. The students' answers were well aligned with the out-of-range indoor air and light quality in the classroom.

The used methodology is capable of being easily generalized and replicable in different similar contexts collecting the specific data and information. Indeed, this flexible approach leads to a wider contribution that has been brought to the current state of art.

As a preliminary theoretical framework proposed by this study, the outcome helps designers to consider the indoor air and light quality issues from the early phase of the project with the specific attention to social, institutional, and technical aspects. Finally, the theoretical framework represents a substantial step towards sustainable development in the contexts of campus buildings.

The main limitation of the present study was related to a lack of appropriate data for assessing a higher number of indicators. Therefore, the indicators will need to be extended and revised through the use of specialized tools in the future with the specific attention to the COVID-19 situation.

Author Contributions: Formal analysis, investigation, methodology, computational analysis, original draft preparation writing, graphic material elaboration, and scenario formulation: F.A.; formal analysis, investigation, computational analysis, original draft preparation, reviewing, and supervision: S.T.M.; methodology, reviewing and supervision: P.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would also like to acknowledge the contributions of Giovanni Carioni, Fabrizio Tonda Roc, Paolo Tronville, Monica Garis, Carlo Deregibus, and all the Green Team experts, who helped in the fulfillment of the present research results and data collection.

Conflicts of Interest: The authors declare no conflict of interest.

References

- [1] T. Lynch, United Nations Sustainable Development Goals: Promoting health and well-being through physical education partnerships, *Cogent Education*. 3 (2016) 1188469.
- [2] R. Bortolini, N. Forcada, Association between Building Characteristics and Indoor Environmental Quality through Post-Occupancy Evaluation, *Energies*. 14 (2021) 1659. <https://doi.org/10.3390/en14061659>.
- [3] M. Azizibabani, M. Dehghani, The Role of Architecture in the Process of Moving towards Sustainable Development, *Journal of Sustainable Architecture and Civil Engineering*. 20 (2017) 25–35.
- [4] R. Costanza, L. Daly, L. Fioramonti, E. Giovannini, I. Kubiszewski, L.F. Mortensen, K.E. Pickett, K.V. Ragnarsdottir, R. De Vogli, R. Wilkinson, Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals, *Ecological Economics*. 130 (2016) 350–355.
- [5] CDC - Indoor Environmental Quality - NIOSH Workplace Safety and Health Topic, (2019). <https://www.cdc.gov/niosh/topics/indoorenv/default.html> (accessed January 25, 2021).
- [6] H.-H. Liang, C.-P. Chen, R.-L. Hwang, W.-M. Shih, S.-C. Lo, H.-Y. Liao, Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan, *Building and Environment*. 72 (2014) 232–242.
- [7] H. Abdulaali, I. Usman, M. Hanafiah, M. Abdulhasan, M. Hamzah, A. Nazal, Impact of poor Indoor Environmental Quality (IEQ) to Inhabitants' Health, Wellbeing and Satisfaction, Pp. Xx-Xx. 1 (2020).
- [8] M. Torabi, M. Mahdavinejad, Past and Future Trends on the Effects of Occupant Behaviour on Building Energy Consumption, *Journal of Sustainable Architecture and Civil Engineering*. 29 (2021) 83–101.
- [9] I. Sarbu, C. Sebarchievici, Aspects of indoor environmental quality assessment in buildings, *Energy and Buildings*. 60 (2013) 410–419. <https://doi.org/10.1016/j.enbuild.2013.02.005>.
- [10] M. Arif, M. Katafygiotou, A. Mazroei, A. Kaushik, E. Elsarrag, Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature, *International Journal of Sustainable Built Environment*. 5 (2016) 1–11.
- [11] S. Marchetti, E. Longhin, R. Bengalli, P. Avino, L. Stabile, G. Buonanno, A. Colombo, M. Camatini, P. Mantecca, In vitro lung toxicity of indoor PM10 from a stove fueled with different biomasses, *Science of The Total Environment*. 649 (2019) 1422–1433. <https://doi.org/10.1016/j.scitotenv.2018.08.249>.
- [12] A. Pacitto, F. Amato, T. Moreno, M. Pandolfi, A. Fonseca, M. Mazaheri, L. Stabile, G. Buonanno, X. Querol, Effect of ventilation strategies and air purifiers on the children's

- exposure to airborne particles and gaseous pollutants in school gyms, *Science of The Total Environment*. 712 (2020) 135673.
- [13] S. Lee, K.S. Lee, A Study on the Improvement of the Evaluation Scale of Discomfort Glare in Educational Facilities, *Energies*. 12 (2019) 3265. <https://doi.org/10.3390/en12173265>.
- [14] M. Turunen, O. Toyinbo, T. Putus, A. Nevalainen, R. Shaughnessy, U. Haverinen-Shaughnessy, Indoor environmental quality in school buildings, and the health and wellbeing of students, *International Journal of Hygiene and Environmental Health*. 217 (2014) 733–739.
- [15] F. Arcega-Cabrera, L. Fargher, M. Quesadas-Rojas, R. Moo-Puc, I. Ocegüera-Vargas, E. Noreña-Barroso, L. Yáñez-Estrada, J. Alvarado, L. González, N. Pérez-Herrera, S. Pérez-Medina, Environmental Exposure of Children to Toxic Trace Elements (Hg, Cr, As) in an Urban Area of Yucatan, Mexico: Water, Blood, and Urine Levels, *Bull Environ Contam Toxicol*. 100 (2018) 620–626. <https://doi.org/10.1007/s00128-018-2306-8>.
- [16] A. Ferguson, H. Solo-Gabriele, Children's exposure to environmental contaminants: an editorial reflection of articles in the IJERPH special issue entitled, "children's exposure to environmental contaminants," (2016).
- [17] A. Iglesias-González, E.M. Hardy, B.M.R. Appenzeller, Cumulative exposure to organic pollutants of French children assessed by hair analysis, *Environment International*. 134 (2020) 105332. <https://doi.org/10.1016/j.envint.2019.105332>.
- [18] F. Ma, C. Zhan, X. Xu, Investigation and Evaluation of Winter Indoor Air Quality of Primary Schools in Severe Cold Weather Areas of China, *Energies*. 12 (2019) 1602. <https://doi.org/10.3390/en12091602>.
- [19] Y. Zhu, X. Li, L. Fan, L. Li, J. Wang, W. Yang, L. Wang, X. Yao, X. Wang, Indoor air quality in the primary school of China – results from CIEHS 2018 study, *Environmental Pollution*. 291 (2021) 118094. <https://doi.org/10.1016/j.envpol.2021.118094>.
- [20] M. Zinzi, F. Pagliaro, S. Agnoli, F. Bisegna, D. Iatauro, On the Built-Environment Quality in Nearly Zero-Energy Renovated Schools: Assessment and Impact of Passive Strategies, *Energies*. 14 (2021) 2799. <https://doi.org/10.3390/en14102799>.
- [21] N.M. Jamaludin, N. Mahyuddin, F.W. Akashah, Assessment of indoor environmental quality (IEQ): Students well-being in University classroom with the application of landscaping, in: *MATEC Web of Conferences*, EDP Sciences, 2016: p. 00061.
- [22] M. Tahsildoost, Z.S. Zomorodian, Indoor environment quality assessment in classrooms: An integrated approach, *Journal of Building Physics*. 42 (2018) 336–362.
- [23] M. Badeche, Y. Bouchahm, A study of Indoor Environment of Large Glazed Office Building in Semi Arid Climate, *Journal of Sustainable Architecture and Civil Engineering*. 29 (2021) 175–188.
- [24] I. Annesi-Maesano, N. Baiz, S. Banerjee, P. Rudnai, S. Rive, the SINPHONIE Group, Indoor Air Quality and Sources in Schools and Related Health Effects, *Journal of Toxicology and Environmental Health, Part B*. 16 (2013) 491–550. <https://doi.org/10.1080/10937404.2013.853609>.
- [25] R. Veenhoven, Conclusions (Chapter 11) of "How harmful is happiness? Consequences of enjoying life or not", *Universitaire Pers Rotterdam*, The Netherlands, 1989.

- [26] J.M. Daisey, W.J. Angell, M.G. Apte, Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information, *Indoor Air*. 13 (2003).
- [27] S. Kubba, *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*, Butterworth-Heinemann, 2012.
- [28] M. Turunen, T. Putus, A. Nevalainen, R. Shaughnessy, U. Haverinen Shaughnessy, Assessment Of Health And Performance Of Sixth Grade Students And Indoor Environmental Quality In Finnish Elementary Schools, *Headache* 49. no.50 (n.d.) 26–27.
- [29] A. Shamseldin, Improvement of the Psychological Lighting Effect Assessment in the Environmental Building Rating Systems, *Journal of Sustainable Architecture and Civil Engineering*. 29 (2021) 102–120.
- [30] H.S. Abdulaali, I.M.S. Usman, M.M. Hanafiah, M.J. Abdulhasan, M.T. Hamzah, A. Nazal, Impact of poor Indoor Environmental Quality (IEQ) to Inhabitants' Health, Wellbeing and Satisfaction, *International Journal of Advanced Science and Technology*. 29 (2020).
- [31] M.A. Sulaiman, W.W. Yusoff, W.W. Kamarudin, Evaluation of Indoor Environmental Quality (IEQ) on dense Academic Building: Case Studies Universiti Tun Hussein Onn Malaysia, *International Journal of Scientific and Research Publications*. 3 (2013).
- [32] M.F. Khamidi, S.N.A. Wahab, N.M. Zahari, POST OCCUPANCY EVALUATION (POE) AND INDOOR ENVIRONMENTAL QUALITY (IEQ) ASSESSMENT: A CASE STUDY OF UNIVERSITI TEKNOLOGI PETRONAS NEW ACADEMIC COMPLEX, *Journal of Design + Built*. 6 (2013). <http://spaj.ukm.my/jsb/index.php/jdb/article/view/101> (accessed March 4, 2021).
- [33] D.-X. Zhao, B.-J. He, F.-Q. Meng, The green school project: A means of speeding up sustainable development?, *Geoforum*. 65 (2015) 310–313. <https://doi.org/10.1016/j.geoforum.2015.08.012>.
- [34] H. Meiboudi, A. Lahijanlian, S.M. Shobeiri, S.A. Jozi, R. Azizinezhad, Development of a new rating system for existing green schools in Iran, *Journal of Cleaner Production*. 188 (2018) 136–143. <https://doi.org/10.1016/j.jclepro.2018.03.283>.
- [35] S.A. UWI, Consideration of the UI Green Metrics: The UWI Performance, (2016).
- [36] The WELL Building Standard-v1, (2016). scienceguide.nl/wp-content/uploads/2018/09/The-WELL-Building-Standard-v1-with-May-2016-addenda.pdf (accessed April 26, 2020).
- [37] Educational Facilities Pilot Addenda | WELL v1, (n.d.). <https://resources.wellcertified.com/tools/educational-facilities-pilot-addenda> (accessed January 8, 2021).
- [38] O. Heath, V. Jackson, E. Goode, Creating positive spaces using the WELL Building standard™, (2018).
- [39] H.H. Ali, S.F. Al Nsairat, Developing a green building assessment tool for developing countries – Case of Jordan, *Building and Environment*. 44 (2009) 1053–1064. <https://doi.org/10.1016/j.buildenv.2008.07.015>.
- [40] J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, J.-H. Zhao, Review on multi-criteria decision analysis aid in sustainable energy decision-making, *Renewable and Sustainable Energy Reviews*. 13 (2009) 2263–2278. <https://doi.org/10.1016/j.rser.2009.06.021>.

- [41] Z. Ishak, S.L. Fong, S.C. Shin, SMART KPI Management System Framework, in: 2019 IEEE 9th International Conference on System Engineering and Technology (ICSET), Malaysia, 2019: pp. 172–177. <https://doi.org/10.1109/ICSEngT.2019.8906478>.
- [42] M.Y. (Annie) Ho, J.H.K. Lai, H. (Cynthia) Hou, D. Zhang, Key Performance Indicators for Evaluation of Commercial Building Retrofits: Shortlisting via an Industry Survey, *Energies*. 14 (2021) 7327. <https://doi.org/10.3390/en14217327>.
- [43] W.Z.W. Yusoff, M.A. Sulaiman, Sustainable campus: Indoor Environmental Quality (IEQ) performance measurement for Malaysian public universities, *European Journal of Sustainable Development*. 3 (2014) 323–323.
- [44] B. Dente, Understanding policy decisions, in: *Understanding Policy Decisions*, Springer, Cham, 2014: pp. 1–27.
- [45] E. Løken, Use of multicriteria decision analysis methods for energy planning problems, *Renewable and Sustainable Energy Reviews*. 11 (2007) 1584–1595. <https://doi.org/10.1016/j.rser.2005.11.005>.
- [46] S. Torabi Moghadam, J. Toniolo, G. Mutani, P. Lombardi, A GIS-statistical approach for assessing built environment energy use at urban scale, *Sustainable Cities and Society*. 37 (2018) 70–84. <https://doi.org/10.1016/j.scs.2017.10.002>.
- [47] M. Noussan, G. Carioni, L. Degiorgis, M. Jarre, P. Tronville, Operational performance of an Air Handling Unit: insights from a data analysis, *Energy Procedia*. 134 (2017) 386–393.
- [48] H. Talei, D. Benhaddou, C. Gamarra, H. Benbrahim, M. Essaïdi, Smart Building Energy Inefficiencies Detection through Time Series Analysis and Unsupervised Machine Learning, *Energies*. 14 (2021) 6042. <https://doi.org/10.3390/en14196042>.
- [49] Y. Hamidi, M. Malha, A. Bah, Study of Four Passive Second Skin Façade Configurations as a Natural Ventilation System During Winter and Summer, *Journal of Sustainable Architecture and Civil Engineering*. 28 (2021) 94–105.
- [50] D. Rasali, R. Zhang, K. Guram, S. Gustin, D.I. Hay, Priority health equity indicators for British Columbia: Selected indicators report, Vancouver, 2016. <https://resourceyourcommunity.com/wp-content/uploads/2018/12/Priority-health-equity-indicators-for-BC.pdf>.
- [51] G. Gorini, A. Gasparrini, E. Tamang, M. Nebot, M.J. Lopez, M. Albertini, D. Marcolina, Group, the E.E. Working, E.E.W. Group, Prevalence of second-hand smoke exposure after introduction of the Italian smoking ban: the Florence and Belluno survey, *Tumori Journal*. 94 (2008) 798–802.
- [52] M.R. Gualano, F. Bert, G. Scaioli, S. Passi, G. La Torre, R. Siliquini, Smoking ban policies in Italy and the potential impact of the so-called Sirchia Law: state of the art after eight years, *BioMed Research International*. 2014 (2014).
- [53] P. Valente, F. Forastiere, A. Bacosi, G. Cattani, S. Di Carlo, M. Ferri, I. Figà-Talamanca, A. Marconi, L. Paoletti, C. Perucci, Exposure to fine and ultrafine particles from secondhand smoke in public places before and after the smoking ban, Italy 2005, *Tobacco Control*. 16 (2007) 312–317.
- [54] M. Numata, M. Sugiyama, W. Swe, D. del Barrio Alvarez, Willingness to Pay for Renewable Energy in Myanmar: Energy Source Preference, *Energies*. 14 (2021) 1505. <https://doi.org/10.3390/en14051505>.

- [55] A. Prozuments, A. Borodinecs, J. Zemitis, Survey based evaluation of indoor environment in an administrative military facility, *Journal of Sustainable Architecture and Civil Engineering*. 27 (2020) 96–107.
- [56] M. Calero-Pastor, F. Mathieux, D. Brissaud, J. Dewulf, A method for supporting the design of efficient heating systems using EU product policy data, *International Journal of Sustainable Engineering*. 10 (2017) 313–325. <https://doi.org/10.1080/19397038.2017.1359859>.
- [57] F. Chirico, A. Sacco, N.L. Bragazzi, N. Magnavita, Can air-conditioning systems contribute to the spread of SARS/MERS/COVID-19 infection? Insights from a rapid review of the literature, *International Journal of Environmental Research and Public Health*. 17 (2020) 6052.
- [58] A. Mohammadi Nafchi, V. Blouin, N. Kaye, A. Metcalf, K. Van Valkinburgh, E. Mousavi, Room HVAC Influences on the Removal of Airborne Particulate Matter: Implications for School Reopening during the COVID-19 Pandemic, *Energies*. 14 (2021) 7463. <https://doi.org/10.3390/en14227463>.
- [59] S.E. Haque, M. Rahman, Association between temperature, humidity, and COVID-19 outbreaks in Bangladesh, *Environmental Science & Policy*. 114 (2020) 253–255.
- [60] J. Wang, K. Tang, K. Feng, W. Lv, High temperature and high humidity reduce the transmission of COVID-19, Available at SSRN 3551767. (2020).
- [61] N. Chipalkatti, Q.V. Le, M. Rishi, Sustainability and Society: Do Environmental, Social, and Governance Factors Matter for Foreign Direct Investment?, *Energies*. 14 (2021) 6039. <https://doi.org/10.3390/en14196039>.
- [62] Q.L. Yu, H.J.H. Brouwers, Indoor air purification using heterogeneous photocatalytic oxidation. Part I: experimental study, *Applied Catalysis B: Environmental*. 92 (2009) 454–461.
- [63] J. Al Dakheel, K. Tabet Aoul, Building Applications, opportunities and challenges of active shading systems: A state-of-the-art review, *Energies*. 10 (2017) 1672.