PORT SAID ENGINEERING RESEARCH JOURNAL

Faculty of Engineering - Port Said University
Volume(28) No. 4 pp: 100-114

Designing Healthy Educational Buildings Based on LEED Rating System

Marwa Mostafa Ahmed [1], Israa ElAwadly [2], Mohamed ElGohary [3]*

[1] *Architecture and Urban Planning Department, Faculty of Engineering, Port Said University, Port Said, Egypt, email: mamostafa482@ gmail.com*

[2] *Architecture and Urban Planning Department, Faculty of Engineering, Port Said University, Port Said, Egypt, email: engisraa2@hotmail.com*

[3] *Architecture and Urban Planning Department, Faculty of Engineering, Port Said University, Port Said, Egypt, email: mgohary2001@yahoo.com*

**Corresponding author,* *DOI: 10.21608/PSERJ.2024.284686.1335*

Received 8-5-2024
Revised 15-7-2024
Accepted 19-8-2024

© 2024 by Author(s) and PSERJ.

This is an open access article licensed under the terms of the Creative Commons Attribution International License (CC BY 4.0). http://creativecommons.org/licenses/by/4.0/

ABSTRACT

A healthy school building is one that has no negative effects on the environment at large or health of its students and occupants. Creating a cozy and healthy interior space is the main goal of the research, which is quantified by indoor environmental quality (IEQ) Foundations for Healthy educational building. It includes indoor air quality, thermal comfort, ventilation, acoustic performance, and lighting which affect how good an indoor environment is in building. Also, the research will base on LEED Rating System, it will use LEED for Building Design and Construction (BD+C) for schools. The focus will be on basic education schools.

Succeed International and local studies have a LEED certificate was selected, analyzed with the climate difference in each study. Methodology was made for designing healthy educational buildings. Case study of a basic education school was selected in Port Said, known for its Mediterranean climate, it was analyzed, conducted a simulation to study lighting in the school's interior environment and evaluated based on methodology to reach a healthy educational school which enhances health of students and occupants.

Keywords: Healthy schools, Indoor environment quality, Visual and Thermal comfort, Acoustics and Indoor air quality, LEED rating system.

1. INTRODUCTION

Strategy of health-promoting schools is improving health and academic achievement in schools [1]. The school building is of great importance. Students spend an amount of time that is second only to the time they spend at home [2]. Student performance and health are significantly impacted by the quality and features of schools. Unfortunately, exposure to environmental issues in schools, such as indoor air pollution, bugs, pesticides, inadequate lighting, and high noise levels, can have a severe impact on the health and performance of both children and staff. Since schools are where students spend the majority of their time while they are not at home, these health issues need to be given careful consideration when developing schools. Consequently, healthy and safe learning environments help kids learn rather than inhibit them.

1. 1 Indoor Environment Quality in Healthy School Building

Quality of the indoor environment (IEQ) for educational buildings is an integral part of establishing high-performing schools and creating a healthy indoor environment for work. It is an indicator of the internal conditions that provide comfort for the users of the space, while respecting the determinants of the external location of the building, factors of ventilation, natural lighting, wind, energy and using of environmentally friendly raw materials [3]. Foundations of (IEQ) are classified into four features as depicted in Figure 1.

Figure 1: Foundations of A Healthy schools

Source: Authors based on [4]

1. 2 Lighting in Healthy Schools

Lighting must be comfortable for all users of the educational building. The quality and color of lighting can either impair or enhance students' visual acuity. Consequently, academic performance. Lighting design is an essential feature of the built environment; the design strategy is complex and requires the integration of natural and electric lighting systems. This process involves designing a learning environment and that has design standards with appropriate windows, shading systems, lighting systems, sensors and controls. This holistic design approach helps produce brighter and healthier learning environments [4], as shown in Table 1.

Table 1. The Design Criteria for Adequate Lighting in Educational Space. Source: Authors based on [6-9].

Quantitatively adequate lighting criteria	Recommendations on classrooms lighting so that they range from (300-500) lux, which prevents dazzling [5].
Maximum room depth to window head height ratios	Widely it recommends a maximum floor depth of twice the ceiling height [6].
Glass Type	There is a preference in schools for using of clear glass and highly reflective or tinted glass should be avoided.
Surface finishing requirements for lighting	- Shiny ceilings and wall surfaces or reflective sources should be avoided to reduce reflections and glare [7]. - The simplest way to choose paint and furniture colors in schools is to choose cool, light colors that are close in degrees. - Floors that are preferred to have a low coefficient of light reflection, while avoiding the white color in the floors.
Lighting control systems in Schools	Systems for controlling natural lighting and Systems that integrate electric lighting with natural lighting into the space.

1. 3 Acoustics and Noise in Healthy Schools

Acoustics of classroom are a crucial aspect of educational environment but usually disregarded. Speaking amongst students or between teachers is a common part of classroom activity, It turns out that environments that supports clear communication are important. Academic performance, conduct, attention span, focus, and reading and spelling skills can all be negatively impacted by excessive echoes and background noise [8]. Reverberation times, signal-to-noise ratios, and background noise are the main causes of acoustic problems in schools. To enhance the acoustic environment in schools, it ought to be managed. As indicated in Table 2, there are acoustic design strategies that need to be taken into account to reduce the impact of background noise on the learning environment.

Table 2. Acoustical design strategies in schools. Source: Authors based on [8-9].

External Background Noise	
Landscape Design	Design of Landscapes To lessen the amount of outside noise that enters classrooms, school buildings must be surrounded by concrete barriers, earthen banks, trees, and plants. [8].
Building of External Walls	In areas where exterior noise levels are high, external walls need to be thick, insulated, and have few openings (such as windows or doors).
Doors and Windows	Windows near loud sources of external noise should be properly installed, heavily weighted, double-paned, and it must be used acoustically-treated curtains in front of windows to reduce the proliferation of external noises in classrooms.
Interior Background Noise	
Noise from Adjacent Spaces	- Separate learning spaces from both internal and external sources of noise (e.g., playgrounds, gymnasiums, music rooms) by using non-acoustically sensitive areas (corridors, storage spaces) as buffer spaces. - Shared classroom walls must be avoided placing adjoining doors.
Materials and Surfaces	- Using acoustically-treated furniture, carpeting and other soft floor finishes and acoustical ceiling tiles to reduce interior noise in classrooms. - Use dense, acoustically treated doors to reduce sound transmission.
Mechanical Noise	Locate mechanical sources of background noise away from critical listening environments and maintain mechanical equipment regularly to reduce internal classroom noise.
Limit for the indoor ambient noise level (dB)	The WHO guidelines recommend less than 35 dB in classrooms to facilitate effective instruction and learning [9].

1. 4 Thermal Health in Healthy Schools

Thermal comfort describes a person's state of mind in terms of whether their temperature is too high or too low [10]. Poor thermal comfort cannot positively affect children's health and academic performance in schools [11]. There are six variables that drive occupant thermal comfort. They can be divided into two categories: personal and environmental factors. [12], as shown in Figure 2. **To guarantee thermal comfort in school, it must put standards to achieve thermal comfort, which will be explained in the following points:**

1. Controlling shade and classroom orientation are key components in achieving thermal comfort [13].
2. It must use curtains in schools to control sunlight. Utilizing insulations to improve classroom thermal comfort and Light-colored paints which reflect light and absorb heat, are very helpful in regulating temperature.
3. Using natural ventilation from properly designed windows, which can moderate the temperature and reduce the energy needed for cooling and also, mechanical ventilation, either with fans, air conditioners, which work as support at times of the year.
4. It is recommended that classroom temperatures be kept between 20 and 24 degrees Celsius in the winter and between 23 and 26 degrees Celsius in the summer [14].
5. According to (ASHRAE standard 55), acceptable relative humidity levels range from 30% to 60% year-round. Excessively high or low relative humidity can produce discomfort [15].

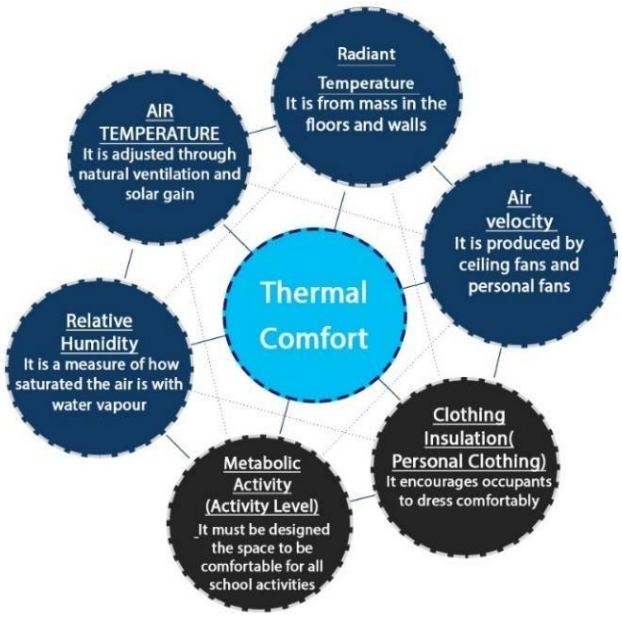


Figure 2: Six Variables in Thermal Comfort

Source: Authors based on [12]

1. 5 Ventilation and Indoor Air Quality in Healthy Schools

There are many different gases and particles present in the air. It could hurt the body because it is too small to see with the unaided eye. We refer to this as indoor air quality [16]. For both students and occupants, schools must be the best places to learn; nevertheless, poor air quality can really have the opposite effect. Indoor pollution levels are expected to be many times higher than outside ones. Given that both adults and children spend as much as ninety percent of their time indoors, this is crucial. Bad indoor air quality can be caused by a number of factors, including mold, chemicals, fumes, volatile organic contaminants (VOCS), carbon dioxide (CO2), and other indoor and outdoor air contaminants; poor air filtration; poor airflow; inadequate ventilation; temperature extremes; and high or low humidity. [17]. A good indoor environment must have excellent indoor air quality (IAQ), which can support schools in achieving their main goal of learning students. IAQ issues can affect staff and teacher performance as well as student attendance, comfort, and performance if they are not prevented [18]. **Therefore, there need to be rules in place to achieve good indoor air quality. It will be explained in the following points:**

1. Increasing outside airflow by opening windows and doors when the weather and safety conditions permit. Making use of fans to get a crosswind or HVAC system and to release room air outside to Improve ventilation [16].
2. Use the proper filtration systems to improve the circulating air's filtration. It must make use of indoor air quality devices that can monitor several air quality issues (such as humidity, temperature, and CO2).

2. LEED RATING SYSTEM

The LEED system offers a framework for environmentally friendly, economically viable, and generally healthy buildings that also improve social welfare, and the environment. The LEED grading system is a globally recognized indicator of leadership and sustainability. A more sustainable and healthful future can be achieved with LEED buildings [19].

2.1 LEED v4.1 Building Design +Construction (BD+C) for Schools

LEED v4.1 is next generation standard for designing, construction, of green building. It includes categories, as shown in Figure 3.

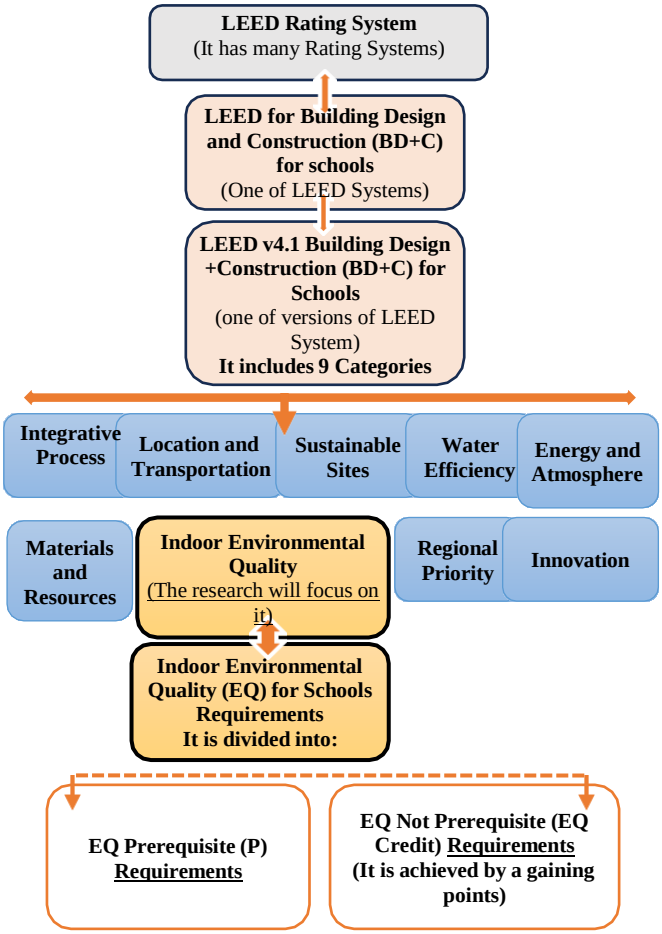


Figure 3: LEED Rating System

Source: Authors based on [19]

2.2 Indoor Environmental Quality (EQ) for Schools Requirements

It is divided into:

1. EQ Prerequisite (P).
2. EQ Not Prerequisite (EQ Credit), as shown in Table 3.

Table 3. Indoor Environmental Quality for schools Requirements. Source: Authors based on [19].

Indoor Environmental Quality for Schools Points (16)		
	1. EQ Prerequisite (P) , It consists of	
Prerequisite	Minimum Indoor Air Quality Performance	P
Prerequisite	Environmental Tobacco Smoke Control	P
Prerequisite	Minimum Acoustic Performance	P
	2. EQ Not Prerequisite(EQ Credit) , It consists of	
Credit	Enhanced Indoor Air Quality Strategies	2
Credit	Low -Emitting Materials	3
Credit	Construction Indoor Air Quality Management Plan	1
Credit	Indoor Air Quality Assessment	2
Credit	Thermal Comfort	1
Credit	Interior Lighting	2
Credit	Daylight	3
Credit	Quality Views	1
Credit	Acoustic Performance	1
Total		16

2.3 EQ Prerequisite Requirements

It is shown in Table 4.

Table 4. Prerequisite Requirements. Source: Authors based on [20-21].

1. **Minimum Indoor Air Quality Performance**
Conditions Mechanically ventilated spaces - Comply with ASHRAE Standard (62.1-2016) or a local equivalent if mechanically ventilated spaces; whichever is more limiting [20]. - Install outdoor air sensors on any system that uses mechanical ventilation. - Before the ventilation system design is finished, the quality of the outside air must be examined [21]. - To enhance indoor air quality, ozone generating devices must be used in accordance with air cleaning devices. - The building envelope and interior surfaces must adhere to weather barriers to stop liquid water from seeping into the envelope, vapor retarders to control the diffusion of water vapor, and air barriers to lessen the unintentional infiltration of pollutants and moisture from the outside air. - The design of buildings with linked parking garages must restrict the amount of vehicle exhaust that enters occupied areas. - In the zone for breathing (Vbz) of the occupiable area, the needed outdoor airflow must not be lower than the value found in ASHRAE Standard (62.1-2016) to comply with Equation. $Vbz = Rp \times Pz + Ra \times Az$ Naturally ventilated spaces - Assemble naturally ventilated areas in accordance with ASHRAE (62.1-2016). - Adhere to one or more of the following monitoring techniques. • Give people access to a direct exhaust airflow measurement tool that can gauge exhaust airflow. • Supply automated signaling devices for all natural ventilation openings meant to satisfy the minimal opening specifications. • Track the amounts of carbon dioxide (CO2) in every heat zone. - The ASHRAE Standard (62.1-2016) Requirements: - A mechanical ventilation system must be included in any zone intended for natural ventilation. There are two limitations to this rule: Building zones that are not supplied by heating or cooling equipment, and zones with controls that keep natural ventilation apertures from closing during times of anticipated occupancy. - The required values for Ceiling Height, Floor Area to be Ventilated, and Opening Sizing must not be less than those found in the ASHRAE Standard 62.1-2016.
2. **Environmental Tobacco Smoke Control**
Conditions - Outlaw smoking in schools to reduce the amount of ambient tobacco smoke that is exposed to building occupants, interior surfaces, and ventilation air distribution systems [20].
3. **Minimum Acoustic Performance**
Conditions Background Noise from HVAC

HVAC systems should be able to produce background noise in classrooms and other important learning areas at a maximum of 40 dBA.

External Noise

Use acoustic treatments and other strategies to reduce outside noise intrusion at high-noise locations.

Reverberation Duration

Every classroom and other essential learning area should be designed to comply with the following requirements:

- The computed reverberation times adhere to ANSI Standard S12.60-2010, which specifies 0.6 s.
- 35 to 55 (dB) is the maximum allowable sound level for background noise in learning areas.

2.4 EQ Not Prerequisite (EQ Credit) Requirements

It is divided into 9 requirements. It is achieved by gaining points. **It will be explained in the following points [20]:**

1. **Strategies of enhanced Indoor Air Quality (1-2 points)**

- Strategy 1: Entryway Systems: Implement entryway systems at regularly used exterior entrances to collect dirt and particles entering school.
- Strategy 2: Internal Cross-Contamination Control: Utilizing the exhaust rates determined in EQ

Prerequisite Minimum Indoor Air Quality Performance.

- Strategy 3: Purification of Outside Air: It is required to install particle filters in every ventilation system.
- Strategy 4: Enhanced Airflow 15 percent
- Strategy 5: Increased Ventilation 30 Percent: The rates of outdoor air ventilation in breathing zones must be raised to at least 30% over the minimum levels in 95% of all occupied spaces.
- Strategy 6: movable Windows: There are movable windows in 75% of educational spaces.
- Strategy 7: Carbon Dioxide Monitoring: It must monitor CO2 concentrations.
- Strategy 8: Extra Source Reduction and Observation: In areas where air pollutants are present, assess possible sources of more air pollutants.

2. **Low -Emitting Materials (1-3 points):** Reducing the concentrations of chemical contaminants that can harm air quality by using materials within the structure that comply with low-emitting sources of VOCs.
3. **Indoor Air Quality Management Plan for Construction (1 point):** It is necessary to safeguard absorbent materials kept on-site against moisture damage. Permanently installed air handling machinery is not used while work.
4. **Indoor Air Quality Assessment (1-2 points):** Perform a building flush-out by supplying air and install new filter media. Perform baseline indoor air quality (IAQ) testing in educational spaces.
5. **Thermal Comfort (1 point) :(**HVAC) systems must be designed to meet the requirements of ASHRAE Standard (55–2017), or a local equivalent. Provide individual and group thermal comfort controls for educational spaces.
6. **Internal Lighting (1-2 points):** It must Glare Control, Color Rendering, Illumination Control, Choose finishes for the interior with a surface reflectivity.
7. **Daylight (1-3 points):** Install glare-control systems. Perform Simulation for Daylight or Illuminance Measurement.
8. **High-quality views (1 point):** The school's occupants must have a view of the surrounding urban or natural surroundings. Glass with a visible light transmittance.
9. **Acoustic Performance (1 point):** HVAC systems must maintain a background noise level of thirty-five dBA or lower. learning spaces should be designed in accordance with ANSI sound transmission class (STC) regulations, or a local equivalent.

3. INTERNATIONAL AND LOCAL STUDIES&CASE STUDY

International and local projects that have a LEED certificate will be studied, where the designer can benefit from these projects before starting the design process, and the researcher can benefit from them when evaluating, and it will be conduct an analytical and evaluative study of a public basic education school in Port Said Governorate through its conformity or closeness to standards of healthy schools. Also, a software simulation will be conducted, the results of the simulation will be presented, and the results will be analyzed. Both international and local studies and case study will be evaluated from Healthy Schools Standards.

3.1 Projects to be studied

1. **International Project**

- Lake Mills Elementary School.

2. **Local Projects**

- Artal Prep School – DQ.
- Ladybird Early Learning Centre.

3. **Case study**

- Sayyida Khadija School for Basic Education.

3.2 Analysis Of International, Local Schools and Case Study

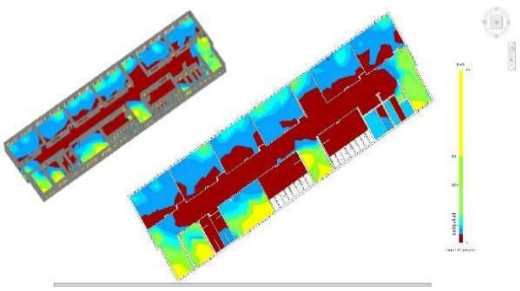
It is shown in Table 5 & Table 6.

Table 5. Analysis Of International and Local Schools. Source: Authors based on [22-27].

		Lake Mills Elementary School.	Artal Prep School – DQ.
Introduction		▪ Location: Wisconsin, United States [22]. ▪ Grade of school: K-12 (K–12 from kindergarten to 12th grade). ▪ Lake Mills Elementary School was opened in 2014. ▪ Number of floors: Two-story. ▪ Total area:93,284 square feet.	▪ Location: Riyadh, Saudi Arabia [25]. ▪ Grade of school: Preparatory school (K– 2 from Nursery to Key Stage 2). ▪ Artal Prep School was established in 2018. ▪ Total area: 18,581 sq ft. ▪ Total number of students:260
Climate		▪ Climate: Continental climate [23]. ▪ Temperature per daytime through year ranges between -3.5 to 27.6 °C.	▪ Climate: Hot desert climate [26]. ▪ Temperature per daytime through year ranges between 20.9 to 43.5 °C.
Indoor Environmental Quality	**Lighting and Visual Comfort**	▪ School relies on Natural and Electric lighting [24]. ▪ The building is positioned in a way that takes advantage of sunlight as much as possible, Orientation is east-west which is ideal for daylight harvesting & passive heating during the winter. ▪ Interior finish & furniture colors & reflectance values were considered for lighting quality & promote daylighting. ▪ The school is equipped with LED lighting with automatic dimming & daylight sensors are in every classroom to help control energy costs. ▪ The interior design is in harmony with the local geography, including landform components, symbolism, and transparency to the outside to establish a link to the surrounding surroundings. Media center features large windows to evoke an open, bright feel, tying students to nature and the outdoors.	▪ School building feature an abundance of natural lighting [27]. ▪ school uses Skylight for natural lighting and providing a visual connection to the outdoor environment to interior occupants. ▪ School provides glare-control systems through tensile Fabric structure and some blocks of building like mashrabiya to control from glare. ▪ Surface reflectance of at least eighty percent for ceilings and fifty-five percent for walls is required for interior finishes. For work surfaces, it employs finishes of furniture with a surface reflectivity of at least forty-five percent. ▪ It is not possible to control in using of windows through operable windows. ▪ The school uses LED lighting with automatic dimming & daylight sensors. ▪ To help children engage with the natural outdoor world, the school features an outdoor garden.
	Acoustics	▪ Thanks to improved acoustics, pupils in the rear of the classroom can clearly hear the teacher. ▪ The school employs acoustic treatments to reduce noise pollution from outside sources and manage the transfer of sound waves between classrooms and other educational areas. ▪ Learning environment furniture is affordable, useful, long-lasting, adaptable, and simple to maintain. Tables and chairs are mobile pieces of furniture. It is easily movable to support a variety of teaching techniques, and furniture with acoustically treated surfaces helps to quiet classrooms.	▪ School has effective acoustic design. ▪ Furniture has wheels and Silicone Rubber to reduce noise in classrooms. ▪ Acoustic wall panels, ceiling finishes have high noise reduction coefficient (NRC). ▪ windows are double-paned and walls with absorptive materials to reduce background noise in learning spaces. ▪ school uses sound-absorbing materials in gymnasium, cafeteria. ▪ school uses to soft floor finishes and acoustic gypsum board ceiling to reduce sound transmission.
	Thermal Comfort	▪ The school provides natural ventilation and mechanical ventilation. ▪ The school building, oriented east-west to maximize passive heating in the winter. ▪ School use operable windows so teachers can open and close them using natural methods to regulate class temperatures. ▪ School has gray roof membrane; it reduces solar heat. ▪ Optimal insulation levels were installed to minimize air infiltration. ▪ There is Geothermal Heating and Cooling System. Geothermal energy is considered a renewable resource and environmentally friendly to heat or cool school.	▪ School uses atrium for Natural ventilation in open area. ▪ Double-pane windows provide school with superior insulation by keeping heat out in the summer. ▪ School uses tensile Fabric structure to protect from both the rain and sun (direct light) which shading control play an important part in creating consistent thermal comfort. ▪ School controls in the temperature which paintings and coatings are light colors, which reflect more light and absorb less heat. ▪ School depends entirely on mechanical heating or cooling, they will consume a lot of energy, generate costs, and can lead to the spread of diseases in very closed environments.

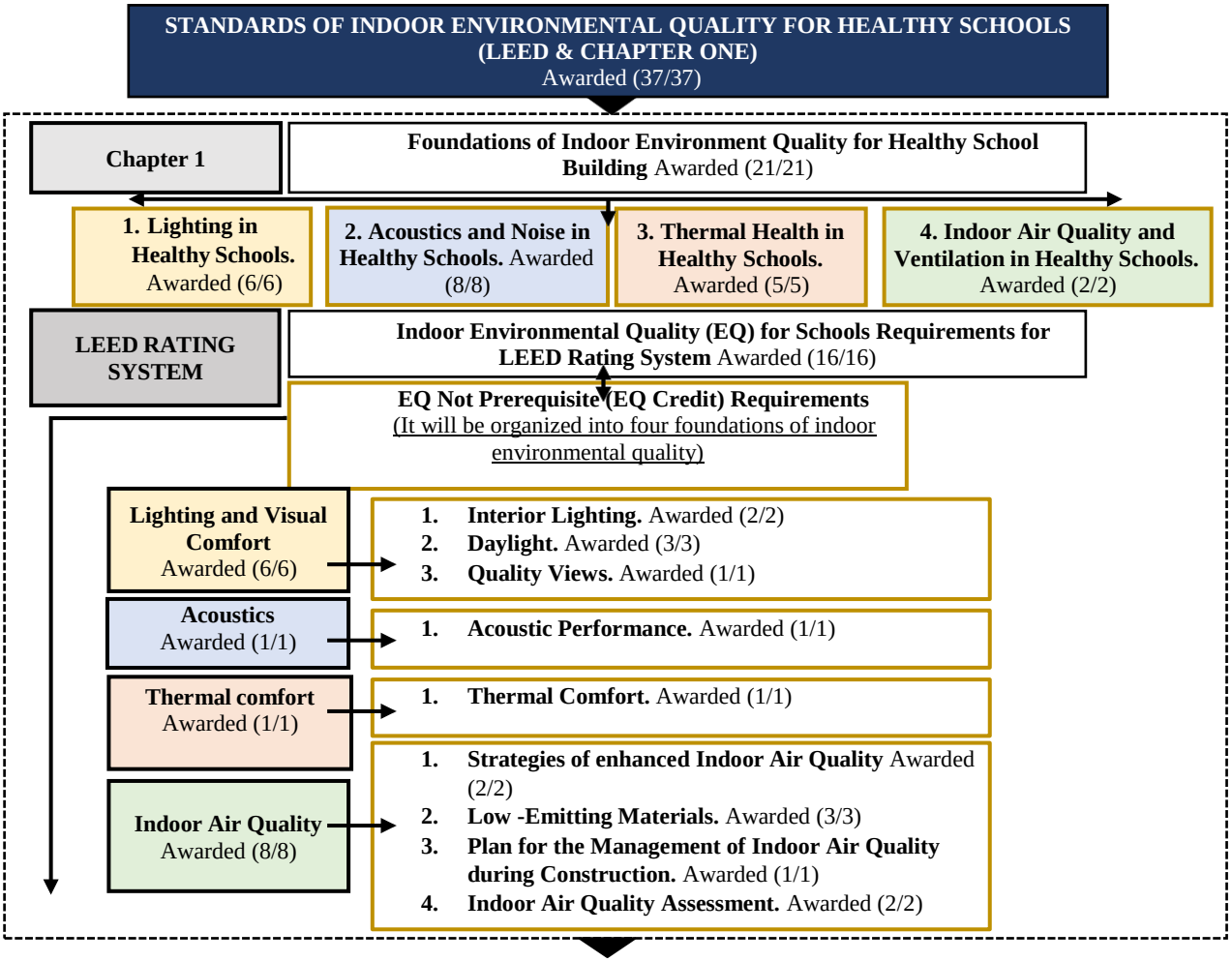
	Indoor Air Quality	▪ School prohibits smoking on campus and in public school buses. ▪ Our school's indoor relative humidity is maintained below 60%. ▪ Ventilation systems in occupied spaces have air-cleaning devices to filter outdoor Air. ▪ Building materials were specifically chosen because they do not contain carcinogenic volatile organic compounds (VOC) or added urea-formaldehyde, which off-gas, triggering allergies, asthma, and other respiratory illnesses. Also, Low -VOC or no-VOC paints, coatings, and flooring, including classroom furniture.	▪ The school looked into outdoor air quality and performed an observational study of the construction site and the area immediately around it to find any nearby pollutants from nearby facilities that would be dangerous to let into the building. ▪ The educational institution offers outside air sensors for every mechanical ventilation system. ▪ To enhance indoor air quality, school deploy ozone generating devices that adhere to Air-Cleaning Devices. ▪ The school does not use Low-VOC building materials.

Table 6. Analysis Of Local and Case Studies. Source: Authors based on [28-31].

		Ladybird Early Learning Centre.	**Sayyida Khadija School for Basic Education (Case Study)**
Introduction		▪ Location: Dubai, United Arab Emirates [28]. ▪ Grade of school: Nursery. ▪ Proposed Lady Bird Nursery was completed on 2022. ▪ Number of floors: Ground-floor only nursery. ▪ Total area: 63,000 square feet.	▪ Location: Port said, Egypt. ▪ Grade of school: State school for basic education (kindergarten - primary - middle school). ▪ Sayyida Khadija School was established in 2017. ▪ Number of floors: Three-story. ▪ Total area :3300 square meter.
Climate		▪ Climate: Hot arid climate [29]. ▪ Temperature per daytime through year ranges between 24.8 to 42.6 °C.	▪ Climate: Mediterranean climate [31]. ▪ Temperature per daytime through year ranges between 19 to 35°C.
Indoor Environmental Quality	**Lighting and Visual Comfort**	▪ Open classrooms and shared learning spaces throughout the nursery create an unrestrained and boundary-free environment using architectural features such as roof overhangs, deeper windows to block out direct sun and to help mitigate thermal heat gain and aluminum louvers are used to reduce heat gain and glare, and the overall orientation of the building for more passive sustainable design strategies [30]. ▪ Nursery makes Simulation Autonomy of Spatial Daylight to spaces that receives sufficient daylight and Exposure of Annual Sunlight to spaces that receives too much direct sunlight. ▪ The interiors of school are light, bright with pastel tones and, of course, ladybirds that delineate the different areas which choosing the right colors can greatly improve children performance and raise their energy and concentration levels and to enhance the quality of lighting. ▪ LED light fittings connected to PIR and light sensors were specified by Ladybird Nursery. A passive infrared sensor (PIR) is a device that uses infrared radiation to detect motion.	▪ Colors of the school's interior finishes are light, but not consistent. The ceiling is painted white, which helps reflect light rays and helps improve the quality of lighting and enhance daylight. The floors are mosaic tiles, which are white. ▪ The school also relied on electric lighting and was equipped with fluorescent lighting units in every classroom. ▪ The simulation of school was conducted on REVIT Program. It was used Lighting Analysis and selected analysis type of LEED. Simulation Results for Ground Floor, there is glare near of windows as shown in Figure 4.  **Figure 4: Results of Ground Floor. [Authors]**

	Acoustics	▪ Situated in a quiet residential street, tucked away from any heavy traffic, you'd be forgiven for not having spotted the new Ladybird Nursery Al Barsha. ▪ Critics of this design approach would refer to problematic acoustics; noise from other classes can be unsettling and distracting for children and can require adults to raise their voices more. it had considered this and put in place design elements in response to this concern. The nursery's ceiling has been specially designed to provide soundproofing, lowering the level of noise that carries through the building. ▪ School uses upholstered furnishings like soft sofa s, chairs on skids instead of four-legged chairs will to reduce interior noise. Fixtures and fittings are appropriately scaled to children's height and appeal to their interests, tables and chairs in the classrooms. ▪ Using soft floor finishes in learning spaces to reduce noise in classrooms.an area with soft safety flooring is set aside for a gym which features climbing walls and tunnels.	▪ The school does not use sound insulation or acoustic treatments to reduce noise leakage from external sources and control the transmission of sound between educational spaces. ▪ The classrooms have non-acoustically treated musky wood doors and the floors are mosaic tiles in classrooms and unglazed ceramic tiles in the laboratory. ▪ Windows are made of aluminum with 6 mm thick transparent glass and the walls are not equipped with absorbent materials in the educational spaces. ▪ There are no drapes on windows., the amount of outside noise will be entered to classroom. ▪ The activity room is located next to the classroom. ▪ The school does not use air conditioning, so it does not have heating and cooling ducts that cause noise. It has good fans in some educational spaces that do not make noise. ▪ The school does not have trees or green areas to reduce amount of external noise that enters educational spaces, but it is surrounded by fences that help reduce noise leakage.
	Thermal Comfort	▪ Natural ventilation through operable windows in glazed façade helps promote an optimum learning environment for both children and teachers. ▪ Nursery used high quality glazed façade to keep glare and heat out of the building which climate is hot arid climate, light-weight high-insulation concrete in construction and insulation from high thermal value materials to help with thermal comfort. ▪ Nursery installed high performance variable refrigerant flow (VRF) units which are highly energy efficient providing zoned comfort with precise temperature control. ▪ According to (ASHRAE standard 55), school achieved acceptable relative humidity levels range from 30% to 60% year-round.	▪ Horizontal sunshades are used in the classrooms on the southeastern facade as a result of direct sunlight, where the use of shading plays an important role in creating thermal comfort. ▪ The school uses natural ventilation from operable windows so students can open and close them to regulate classroom temperatures, reduces the energy needed for cooling, and also uses mechanical ventilation. ▪ The school does not use heating, ventilation and air conditioning (HVAC) systems, but fans are used in some educational spaces. ▪ The school doesn't use light- colored paints, which reflect more light and absorb less heat.
	Indoor Air Quality	▪ Nursery is healthy building, it has optimized cooling and healthy air quality, that ensures youngsters will enjoy a warm, friendly and nurturing environment in which they can play, learn, have fun and evolve during their early years. ▪ Design of this nursery campus to improve air quality and reduce the risk of illnesses being spread. Ladybird Al Barsha has installed system of a UV air purification in the air -conditioning. ▪ Nursery installed permanent entryway systems to capture particles that enter the structure through the entrances. ▪ School has operable windows in glazed façade that provide access to outdoor air. ▪ Nursery envelope contains weather barrier, vapor retarder and air barrier to improve indoor air quality. ▪ Utilizing the exhaust rates established in ASHRAE Standard (52.2–2017) to prevent interior cross-contamination, adequately exhaust every place where hazardous gases may be utilized or present (such as laundry and housekeeping rooms, laboratories).	▪ Every school space has movable windows that let in outside air to improve indoor air quality and increase occupant comfort, well-being, and productivity. ▪ The classroom's interior design was created using plastic paint for the walls and ceiling, a floor constructed of mosaic tiles, a silver aluminum window, a wood door painted with lacquer, and furniture made of MDF veneered countertop wood. The school does not use monitoring systems designed to detect pollutants. ▪ The school layout contains sand, no green spaces and trees, and no paving, and the school was operated before completion of construction of layout. ▪ In Port Said Governorate, humidity ranges between 51 and 64% during the year. ▪ The school relies on natural ventilation and is not served by heating or cooling devices. Fans are used in some educational spaces.

3.3 Methodology



STANDARDS OF INDOOR ENVIRONMENTAL QUALITY FOR HEALTHY SCHOOLS (LEED & CHAPTER ONE) Awarded (37/37)	
Lighting and Visual Comfort Awarded (12/12)	
CHAPTER 1 Awarded (6/6)	▪ Lighting of classrooms ranges from (300-500) lux. **Awarded (1/1)**
	▪ Interior colors are important in determining the quality of lighting, and white is used extensively in classrooms, where the coloring plan is based on cool, light colors with avoid using dark surfaces directly adjacent to windows. **Awarded (1/1)**
	▪ Using natural lighting control systems in schools to overcome visual discomfort and to reduce heat gain. **Awarded (1/1)**
	▪ Using electric lighting control systems to determine level of electric lighting required to reach necessary lighting levels and reduce energy. **Awarded (1/1)**
	▪ Shiny ceilings and wall surfaces or reflective sources should be avoided to reduce reflections and glare. **Awarded (1/1)**
	▪ Maximum floor depth of twice the ceiling height. That will promote good daylighting. **Awarded (1/1)**
LEED Awarded (6/6)	Interior Lighting **Awarded (2/2)**
	Daylight **Awarded (3/3)**
	Quality Views **Awarded (1/1)**
Acoustics Awarded (9/9)	
CHAPTER 1 Awarded (8/8)	▪ To lessen noise entering instructional spaces, schools can be surrounded by concrete, trees, and landscape barriers. **Awarded (1/1)**
	▪ Build insulated, thick external walls. construction and Windows need to be double-paned, strongly weighted, and fitted correctly. To lessen the transmission of sound, doors need to be dense and acoustically treated. **Awarded (1/1)**

	▪ Avoid installing adjacent doors on shared learning spaces walls as this will reduce the amount of sound isolation. **Awarded (1/1)**
	▪ Using curtains with acoustic treatment on windows can help minimize the amount of outside noise that enters classrooms. **Awarded (1/1)**
	▪ Use non-acoustically sensitive sections (corridors, storage spaces) to isolate sound-sensitive places (like learning spaces) from inside and outside noise sources (like playgrounds, music rooms). **Awarded (1/1)**
	▪ Reducing internal noise in classrooms by using furniture that has been acoustically treated. **Awarded (1/1)**
	▪ Reduce noise by using acoustical ceiling tiles, carpeting, and other soft floor finishes. **Awarded (1/1)**
	▪ To lessen internal classroom noise, keep mechanical equipment well-maintained and keep noisy sources like fans, HVAC systems, and malfunctioning lighting fixtures away from sensitive listening areas. **Awarded (1/1)**
LEED Awarded (1/1)	Acoustic Performance. **Awarded (1/1)**
Thermal Comfort Awarded (6/6)	
CHAPTER 1 Awarded (5/5)	▪ Using shading control to control sunlight and increase thermal comfort in schools. **Awarded (1/1)**
	▪ Used materials in a school is very important, from the type of wall and roof to the final coatings. Each climate and each location receive a different thermal load and conditions. Use coatings and insulation that can improve thermal comfort in schools if the building is already built. **Awarded (1/1)**
	▪ Using light-colored paints really aids in temperature regulation. **Awarded (1/1)**
	▪ Sufficient ventilation is essential for both thermal comfort and optimal indoor air quality. This includes both natural and mechanical ventilation, which can be helpful at particular seasons of the year. Comfortable temperature for the classroom must be maintained between 20 degrees and 26 degrees Celsius within year months. To maintain these temperatures during these months is by achieving a high level of thermal performance in all areas of the building envelope. **Awarded (1/1)**
	▪ Acceptable relative humidity levels must range from 30% to 60% year-round. **Awarded (1/1)**
LEED Awarded (1/1)	Thermal Comfort. Awarded **(1/1)**
Indoor Air Quality Awarded (10/10)	
CHAPTER 1 Awarded (2/2)	▪ Every inhabited educational area has movable windows that let in natural light and fresh air. **Awarded (1/1)**
	▪ Fans must be used to create a crosswind and release room air outside. **Awarded (1/1)**
LEED Awarded (8/8)	Strategies of enhanced Indoor Air Quality **Awarded (2/2)**
	Low -Emitting Materials **Awarded (3/3)**
	Plan for the Management of Indoor Air Quality during Construction **Awarded (1/1)**
	Indoor Air Quality Assessment. **Awarded (2/2)**

Figure 5: Methodology for Healthy schools. [Authors]

3.4 Evaluation of International, Local Schools and Case Study

Table 7. Evaluation of International, Local Schools and Case Study. Source: Authors.

STANDARDS OF INDOOR ENVIRONMENTAL QUALITY FOR HEALTHY SCHOOLS (LEED & CHAPTER ONE) Awarded (37/37)		Lake Mills Elementary School	Artal Prep School – DQ	Ladybird Early Learning Centre	Sayyida Khadija School for Basic Education
Lighting and Visual Comfort Awarded (6/6)		**Awarded**	**Awarded**	**Awarded**	**Awarded**
CHAPTER 1	▪ Lighting of classrooms ranges from (300-500) lux.	(0/1)	(0/1)	(1/1)	(0/1)
	▪ Interior colors are important in determining the quality of lighting, and white is used extensively in classrooms, where the coloring plan is based on cool, light colors with avoid using dark surfaces directly adjacent to windows.	(1/1)	(1/1)	(1/1)	(0/1)
	▪ Using natural lighting control systems in schools to overcome visual discomfort and to reduce heat gain.	(1/1)	(1/1)	(1/1)	(1/1)
	▪ Using electric lighting control systems to determine level of electric lighting required to reach necessary lighting levels and reduce energy.	(1/1)	(0/1)	(1/1)	(0/1)
	▪ Shiny ceilings and wall surfaces or reflective sources should be avoided to reduce reflections and glare.	(1/1)	(1/1)	(1/1)	(0/1)
	▪ Maximum floor depth of twice the ceiling height. That will promote good daylighting.	(1/1)	(1/1)	(1/1)	(1/1)

Lighting and Visual Comfort Awarded (6/6)			**Awarded**		**Awarded**		**Awarded**		**Awarded**	
LEED RATING SYSTEM	Interior Lighting Awarded (2/2)	▪ Attain one approach for a single point. Reach a total of three approaches for two points. approaches: 1. control of glare. 2. Rendering of Color. 3. Lighting Control. 4. Reflectivity on the Surface.	(1 / 2)		(1 / 2)		(1 / 2)		(0 / 2)	
	Daylight Awarded (3/3)	▪ Make sure every inhabited space has glare-control equipment installed. ▪ Choose any one of the subsequent three choices: First option (1-3 points) Simulation: Exposure of Annual Sunlight 1000,250 and Autonomy of Spatial Daylight 300/50%.Second option (1-3 points) Simulation: Calculations of Illuminance. Choice 3 (1-3 points) measurement of the light intensity in every area that is frequently used.	(0 / 3)		(0 / 3)		(3 / 3)		(0/ 3)	
	Quality Views Awarded (1/1)	▪ Provide views to the natural or urban environment for occupants in the building through glass with a visible light transmittance.	(1 / 1)		(0 / 1)		(1 / 1)		(0 / 1)	
Points Total of Lighting and Visual Comfort (LEED& CH 1) Awarded (12/12)			Awarded	%	Awarded	%	Awarded	%	Awarded	%
			(7/12)	58.3 %	(5/12)	41.7 %	(11/12)	91.7 %	(2/12)	16.7 %
Average percentage total (%)			52.1%							
Acoustics Awarded (8/8)			**Awarded**		**Awarded**		**Awarded**		**Awarded**	
CHAPTER 1	▪ To lessen noise entering instructional spaces, schools can be surrounded by concrete, trees, and landscape barriers.		(1/1)		(1/1)		(1/1)		(1/1)	
	▪ Build insulated, thick external walls. construction and Windows need to be double-paned, strongly weighted, and fitted correctly. To lessen the transmission of sound, doors need to be dense and acoustically treated.		(0/1)		(0/1)		(0/1)		(0/1)	
	▪ Avoid installing adjacent doors on shared learning spaces walls as this will reduce the amount of sound isolation.		(1/1)		(1/1)		(1/1)		(1/1)	
	▪ Using curtains with acoustic treatment on windows can help minimize the amount of outside noise that enters classrooms.		(0/1)		(0/1)		(0/1)		(0/1)	
	▪ Use non-acoustically sensitive sections (corridors, storage spaces) to isolate sound-sensitive places (like learning spaces) from inside and outside noise sources(like playgrounds, music rooms).		(1/1)		(1/1)		(1/1)		(0/1)	
	▪ Reducing internal noise in classrooms by using furniture that has been acoustically treated.		(1/1)		(1/1)		(1/1)		(1/1)	
	▪ Reduce noise by using acoustical ceiling tiles, carpeting, and other soft floor finishes.		(1/1)		(1/1)		(1/1)		(0/1)	
	▪ To lessen internal classroom noise, keep mechanical equipment well-maintained and keep noisy sources like fans, HVAC systems, and malfunctioning lighting fixtures away from sensitive listening areas.		(1/1)		(1/1)		(1/1)		(1/1)	

Acoustics Awarded (1/1)			**Awarded**		**Awarded**		**Awarded**		**Awarded**			
LEED RATING	Acoustic Performance Awarded (1/1)	▪ Obtain level of background noise of 35 dBA or lower from HVAC systems. ▪ School classrooms need to meet the ANSI class of sound transmission regulations or an equivalent local standard.	(0 / 1)		(0 / 1)		(0 / 1)		(0 / 1)			
Points Total of Acoustics (LEED& CH 1) Awarded (9/9)			**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**		
			(6/9)	66.7 %	(6/9)	66.7 %	(6/9)	66.7 %	(4/9)	44.4 %		
Average percentage total (%)			61.12%									
Thermal Comfort Awarded (5/5)			**Awarded**		**Awarded**		**Awarded**		**Awarded**			
CHAPTER 1	▪ Using shading control to control sunlight and increase thermal comfort in schools.		(1/1)		(1/1)		(1/1)		(1/1)			
	▪ Used materials in a school is very important, from the type of wall and roof to the final coatings. Each climate and each location receive a different thermal load and conditions. Use coatings and insulation that can improve thermal comfort in schools if the building is already built.		(1/1)		(1/1)		(1/1)		(0/1)			
	▪ Using light-colored paints really aids in temperature regulation.		(0/1)		(1/1)		(1/1)		(0/1)			
	▪ Sufficient ventilation is essential for both thermal comfort and optimal indoor air quality. This includes both natural and mechanical ventilation, which can be helpful at particular seasons of the year. Comfortable temperature for the classroom must be maintained between 20 degrees and 26 degrees Celsius within year months. To maintain these temperatures during these months is by achieving a high level of thermal performance in all areas of the building envelope.		(1/1)		(0/1)		(1/1)		(0/1)			
	▪ Acceptable relative humidity levels must range from 30% to 60% year-round.		(1/1)		(0/1)		(1/1)		(0/1)			
Thermal Comfort Awarded (1/1)			**Awarded**		**Awarded**		**Awarded**		**Awarded**			
LEED RATING SYSTEM	Thermal Comfort Awarded (1/1)	▪ Heating, ventilating, and air-conditioning (HVAC) systems must be achieved the requirements of ASHRAE Standard or a local equivalent. Provide thermal comfort controls for educational spaces.	(1 / 1)		(0 / 1)		(1 / 1)		(0/ 1)			
Points Total of Thermal Comfort (LEED& CH 1) Awarded (6/6)			**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**		
			(5/6)	83.3 %	(3/6)	50%	(6/6)	100 %	(1/6)	16.7 %		
Average percentage total (%)			62.5%									
Indoor Air Quality Awarded (2/2)			**Awarded**		**Awarded**		**Awarded**		**Awarded**			
CHAPTER 1	▪ Every inhabited educational area has movable windows that let in natural light and fresh air.		(1/ 1)		(0 / 1)		(1 / 1)		(1/ 1)			
	▪ Fans must be used to create a crosswind and release room air outside.		(0 / 1)		(0 / 1)		(1 / 1)		(0/ 1)			
Indoor Air Quality Awarded (8/8)			**Awarded**		**Awarded**		**Awarded**		**Awarded**			
LEED RATING SYSTEM	Strategies of enhanced Indoor Air Quality Awarded (2/2)	▪ Comply the strategies: Entryway Systems. Interior Cross-Contamination Prevention. Filtration of Outdoor Air. Increased Ventilation 15 Percent. Increased Ventilation 30 Percent. Operable Windows. Carbon Dioxide Monitoring. Extra Source Control and Observation.	(1 / 2)		(1 / 2)		(2 / 2)		(0/ 2)			

	Low - Emitting Materials Awarded (3/3)	▪ Materials of the building interior must be achieved low-emitting sources of VOCs. Awarded points are depend on how many achieved product categories. Product categories: Paints and Coatings. Adhesives and Sealants. Flooring. Wall panels. Ceilings. Insulation. Furniture. Composite wood.	(2 / 3)		(0 / 3)		(0 / 3)		(0 / 3)	
	Plan for the Management of Indoor Air Quality during Construction Awarded (1/1)	▪ Prevent moisture damage to absorbent materials that are kept on site. ▪ During construction, avoid using long-term air-handling machinery unless media of filtration meets the ASHRAE Standard (52.2).	(1 / 1)		(0 / 1)		(1 / 1)		(0/ 1)	
	Indoor Air Quality Assessment Awarded (2/2)	▪ Choose one of the next two choices to be executed upon the completion of construction. Option 1: (1 point) Prior to occupancy, install new filtering media and supply air to the building to complete a building flush-out. Option 2 (1-2 points) Check indoor air quality for pollutants in inhabited spaces.	(0 / 2)		(0 / 2)		(1 / 2)		(0 / 2)	
Points Total of Indoor Air Quality (LEED& CH 1) Awarded (10/10)			**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**
			(5/10)	50%	(1/10)	10%	(6/10)	60%	(1/10)	10 %
Average percentage total (%)			32.5%							
TOTAL OF INDOOR ENVIRONMENTAL QUALITY STANDARDS			**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**	**Awarded**	**%**
			(23/37)	**62.2 %**	**(15/37)**	**40.5 %**	**(29/37)**	**78.3 %**	**(8/37)**	**21.6 %**

4. RESULTS AND DISCUSSION

The research concluded the importance of healthy schools and its role in that it does not negatively affect the health of its students and occupants or the environment. It focused on quality of indoor environment, in addition to relying on the LEED classification system. Criteria were deduced to achieve healthy educational buildings. Then successful international studies were analyzed. And also, a case study in Port Said Governorate was chosen, analyzed and it was concluded that:

- Color of floors tiles is white, which leads to visual discomfort within the educational space.
- There is glare on the floors in the classroom causing visual discomfort.
- There are no green spaces in site of school, so the green color cannot be seen from any educational space.
- The school is located on main street in a residential area. There is noise leakage from external sources in educational spaces.
- Windows are made of aluminum with 6 mm thick transparent glass and the walls are not equipped with absorbent materials in the educational spaces.
- There are no drapes on windows.
- Fans are employed in certain instructional areas, but the school does not have HVAC systems.
- The school doesn't make use of monitoring tools meant to find pollutants.
- A person feels uncomfortable in high humidity, which can exceed 64% of the year.
- To lower amounts of chemical contaminants that can be harmful to the environment and air quality, the interior of the building must be made of materials that comply with low-VOC sources.

5. CONCLUSION

Research is presented on healthy educational buildings and its role in enhancing students and occupants' health and performance.IT focuses on indoor environment of school. It was concluded methodology to achieve healthy indoor environment of school. It can be summarized in the most important points:

Lighting and Visual Comfort:

- Lighting of classrooms ranges from (300-500) lux.
- Shiny ceilings and wall surfaces or reflective sources should be avoided to reduce reflections and glare.
- Maximum floor depth of twice the ceiling height. That will promote good daylighting.
- Make sure every educational space has glare-control equipment installed.
- Do Simulation: Exposure of Annual Sunlight 1000,250 and Autonomy of Spatial Daylight 300/50%
- Provide views to the natural or urban environment for students in school through glass with a visible light transmittance.

Acoustics:

- To lessen noise entering instructional spaces, schools can be surrounded by concrete, trees, and landscape barriers.
- Avoid installing adjacent doors on shared learning spaces walls as this will reduce the amount of sound isolation.
- Reduce noise by using acoustical ceiling tiles, carpeting, and other soft floor finishes.
- Obtain level of background noise of 35 dBA or lower from HVAC systems.

Thermal Comfort:

- Using shading control to control sunlight and increase thermal comfort in schools.
- Sufficient ventilation is essential for both thermal comfort and optimal indoor air quality. This includes both natural and mechanical ventilation.
- Acceptable relative humidity levels must range from 30% to 60% year-round.
- Heating, ventilating, and air-conditioning (HVAC) systems must be achieved the requirements of ASHRAE Standard or a local equivalent. Provide thermal comfort controls for educational spaces.

Indoor Air Quality:

- Every educational space has openable windows that let in natural light and fresh air.
- Fans must be used to create a crosswind and release room air outside.
- Install permanent entryway systems at least 10 feet (3 meters) to capture dirt and particulates entering the building at regularly used exterior entrances.
- Install monitoring systems with sensors designed to detect the specific contaminants.
- Materials of school interior must be achieved low-emitting sources of VOCs.
- Prevent moisture damage to absorbent materials that are kept on site.
- Prior to occupancy of school, install new filtering media and supply air to school to complete a building flush-out.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Declaration of Funding

There is no funding.

6. REFERENCES

[1] World Health Organization and the United Nations Educational, Scientific and Cultural Organization.2021. Making every school a health-promoting school.

[2] Healthy Buildings for Health. Foundations for Student Success.

[3] Journal of Research in the Fields of Specific Education. 2022. Ways to improve the quality of the indoor environment in public basic education schools, thermal comfort/lighting.

[4] Healthy Buildings for Health. Foundations for Student Success.

[5] 4th International Conference on Energy and Environment Research.2017. Improving visual comfort and energy efficiency in existing classrooms using passive daylighting techniques.

[6] Francesco De Luca.2020. Daylight in schools' guidance.

[7] Amira Ahmed Muhammad Hussein. 2018. Analysis and evaluation of the interior design elements of educational buildings through the concept of sustainability (primary schools).

[8] Ceilings & interior systems construction association. Acoustics in Schools.

[9] World Health Organization (WHO). Noise.

[10] Health and Safety Executive (HSE). Thermal comfort.

[11] World Green Building Council (World GBC). Thermal Comfort in Schools.

[12] Rocky Mountain Institute (RMI). 2016. Thermal Comfort in Buildings.

[13] ugreen.io.2022.the-importance-of-thermal-comfort-in-schools.

[14] ies.ed.gov.2018. Optimal classroom temperature to support student learning.

[15] Building. 2019. Guidance on thermal comfort in the learning environment.

[16] American Lung Association. Indoor Air Quality in Schools Guide.

[17] Sahar m. Mansour.2014. indoor air quality in schools: an investigation of the impact of outdoor air quality, school layout, and room type.

[18] U.S. Environmental Protection Agency. Reference Guide for Indoor Air Quality in Schools.

[19] U.S. Green Building Council. org.

[20] U.S. Green Building Council. 2022. LEED v4.1Building design and construction.

[21] ANSI/ASHRAE Standard 62.1-2019. Ventilation for Acceptable Indoor Air Quality.

[22] www.usgbc.org.2016.lake-mills-elementary-school.

[23] worlddata.info/america/usa/climate-wisconsin.php.
[24] U.S. Department of Education Green Ribbon Schools2014-2015. Lake Mills Elementary School.
[25] usgbc.org/projects/artal-prep-school-dq.
[26] worlddata.info/asia/saudi-arabia/climate-najd.php.
[27] artalschools.edu.sa/school.php.
[28] usgbc.org/projects/proposed-lady-bird-nursery.
[29] worlddata.info/asia/arab-emirates/climate-dubai.php.
[30] Ladybirdnursery.ae/al-barsha.
[31] worlddata.info/africa/egypt/climate-nile-delta.php.