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Review Article

Green School Buildings and Environmental Holistic Elements Approach to Cope with Hot and Humid Climate Challenges – Bahrain Case Study

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Abstract

Public schools in Bahrain and in the Arabian Gulf Region are facing poor indoor and outdoor environments due to the prevailing problem of harsh hot humid weather most of the year. This leads to high consumption of energy, and other resources due to the nature function of the schools. This necessitates effective actions to fill the gap and address properly the climate issues, consumption of resources, and design challenges. Reviewing related literature indicated a lack of Arab region studies in this field, in contrast to Foreign Studies. This gap includes items such as knowledge, data collection, design flaws, performance, guidelines and others. The objectives of this article are to investigate, and identify factors, green elements and possible solutions contributing to sustaining green public-school buildings and the environment while saving national resources and meeting performance sustainable criteria for school buildings and students. Literature review and qualitative descriptive method are essential investigation methodologies. The goal of qualitative descriptive studies is a comprehensive summarization and categorical. Literature review was the main action in the process to start exploring prior research and published works on green school buildings. Collected data on research materials published by reliable professional institutions and research are reviewed, explored, identified, categorized, and summarized in outputs. These are discussed and analyzed to ensure their positive influence on schools' buildings and address collective challenges. Findings can be summarized in the following outputs: Characteristics. Advantages. Guidelines and standards. Green Building Council's influence. Performance and rating tools for schools and students. Statistics. Innovation and Case studies and Lessons learned. The first Bahrain green school case study will contribute to the exchange experience with others concerned. In conclusion, this article recommends greening school buildings and environment design through various sustainable elements that are included in the results to enhance school buildings, the environment and student performance.

Keywords: Sustainable Design; Green School Buildings; Climate Challenges; Lessons Learned; Hot-Humid Climate; Bahrain.

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1. Introduction

In a fast changing, world, that is characterized by changes such as climate, environmental, economic, social, political, behavioral, belief, human health and well-being. Unfortunately, most of these changes are affecting adversely our planet and endangering human life and other creatures. These changes are due to either natural phenomena and/or human activities. For instance, global warming is one of the outcomes attributed to human activities because of polluting the environment affecting the quality-of-life components negatively. Despite proposing and adopting various possible solutions to address this catastrophic unbalanced climatic and environmental issue through research work, international conferences, ecological agreements to meet environmental, climatic, and other obligations targets, still the positive impact of all of these on environment remains limited. Thus, necessitates further urgent planned scientific innovative actions to continuously boost minimizing the emissions, saving the energy and water consumption efficiently, and optimizing natural resources utilization in the context of greening and sustainability. Accordingly, this article is going to address the root causes of some of these environmental and climatic problems by focusing on greening our school buildings and their surrounding environment due to their importance in reducing their ecological "footprints" while increasing their ecological "handprints" resulting in "Net Positive". It is estimated that 25% of the expenses on energy in schools could be saved through better building design and using energy-efficient technologies combined with improvements in operations and maintenance [1], [2]**.** School buildings are generally of high-energy and water consumptions, in addition to other various resources requirements, including building services, systems and facilities, to cope with their high occupancy levels and unique occupancy patterns. Therefore, this article focuses on an integrated approach to greening public-school buildings and the environment. School campuses usually accommodate students from the age of five to eighteen years, in addition to the teaching, administrative, and other concerned staff for the effective and efficient functioning of the school. Green architectural characteristics can contribute to creating high performance school buildings and environment. Moreover, adopting sustainability through the whole life cycle of a school

project inculcates in the students from their early ages practicing sustainability to become an embedded better daily lifestyle and behavior.

2. Literature Review

This research relied on available literature, interviews, and interactions with architectural and building consultants, educational authorities and students. Literature review was an essential action in the process to start exploring prior research, published works on the role of architecture and building engineering to address climate challenges, high consumption of resources, and find possible and adequate design solutions to poor indoor and outdoor environments and low-level comfort. Therefore, Internet and library research were conducted; institutes and interested concerned parties were approached for their assistance and contributions. The literature review covers the following areas:

2.1. Background of the study

Globally the root to building and environmental sustainability goes back to the 1960s and early 1970s as a reaction to oil price increases. This led to significant research and activities to improve energy efficiency and find alternative renewable energy sources with less impact on environment and quality of life [1], [2], [39]. This process towards improved green sustainability is being developed gradually to achieve higher performance and optimal cost. The greening of school buildings and environment is part of this process, which started in the early 1990s and still is going on [3], [6]. Concerned organizations in many countries established their own performance rating for assessing sustainability for their school buildings and environment, in addition, to adopting BREAM, LEED [4]. One such organization is the Green Building Councils that are available in more than 90 countries worldwide. Their mission is to facilitate the global transformation of the building industry towards sustainability through market driven mechanisms. The Construction Projects Directorate (CPD) of the Ministry of Works at the Kingdome of Bahrain is responsible for handling public building projects. In 2010, CPD introduced the green building initiative for public buildings, particularly schools. In December 2021 the Green Building Manual of Bahrain under (Law 212, 2019) was enforced to create an excellent city that provides the essence of success and comfort of living while optimizes resources utilization [3], [5]. There are about 210 public

schools at Bahrain of different levels. The main case study in this article focuses on the first Public Green School that was completed in 2016 under the name of Girls Primary/Intermediate School at Wadi Al-Sail - West Riffa, Kingdom of Bahrain. More green schools were built in Bahrain after the completion of this first school [6]. Revealing the benefits and other positive aspects of greening school buildings to their concerned stakeholders will give them the opportunity to take adequate decisions concerning schools' sustainability policies and guidelines [4], [7].

2.1.1 Theories

In the context of this article, Greening a school building and its surrounding environment involves actions that help reduce the negative and harmful effects on our climate and natural environment all through its design strategy, construction process, operation and behavior of the students and other users. The definitions of other used terminologies such as sustainability and greening of buildings, schools and environment are subjective and possibly need to be framed within a specific context to hold specific required meaning, therefore the following definitions and outline theories that are related to the context of this article on sustainability and greening of buildings particularly schools:

- Sustainability: the creation and responsible management of a healthily built environment based on resource efficiency and ecological principles. [6]**,** [8]**.**
- Sustainability: is defined by the World Commission on Environment and Development as meeting the needs of today without compromising the ability of future generations to meet their own needs [6]**,** [8]**.**
- Sustainable Building is defined as a fully integrated; "whole building" approach to design, construction, and operation. Sustainable buildings are also referred to as green or high-performance buildings designed to provide optimal environmental and economic performance; increase efficiencies thereby saving energy, water, and other resources; furnish satisfying, productive, and quality indoor spaces; use environmentally preferable materials; and educate building occupants about efficiency and conservation [6]**,** [8].
- Green building is defined as a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health, improving employee

productivity, using energy, water, and other resources more efficiently, and reducing the overall impact to the environment [6], [8].

- Green School is defined by the U.S. Green Building Council (USGBC), as a school building or facilities that create a healthy environment that is conducive to learning as well as saving energy, resources and money [6], [8].
- Green school is the physical result of the consensus process of planning, design, and construction that considers a building's performance over its entire 50- to 60-year life cycle. The green school can provide clean fresh air, a comfortable temperature range, abundant light, and low distraction from unwanted noise, still maximizing resource efficiency, minimizing pollution, and teaching students the importance of innovation in the built environment, also being a teaching tool for sustainability [6], [8], [19].
- A footprint (i.e. carbon footprint) is a measure of the negative impact an individual or organization has on the environment. While a handprint refers to the sum of positive actions taken to better the planet [9], [19].

2.1.2 Concepts

There are many concepts that focus on holistic approaches for designing sustainable green schools. Hereunder, six different main concepts are illustrated, that can be integrated and applied either fully or partially for designing sustainable green schools, depending on the available required resources to fulfil pre-set objectives [9]. Accordingly, there will be a varying impact on the green school performance depending on the level of their application and implementation as illustrated in the section of the results. [10], [11], [12], [13].

School Design Principles

Functional: Schools are primarily places for teaching and learning. [14].

Responsive: Responsive schools are: Consistent with Principles of Education, Equitable for All Learners, Supportive of Wellbeing, Welcoming and Inclusive, Safe, Fit-for-Purpose, and Flexible [14].

Sustainable: It is important that school property can change and adapt to support changes in practices with minimal impact on the environment. Sustainable schools are Environmentally Conscious, Economical, Resilient, and Adaptable [14].

Site, Building Spatial Planning, and Technical Standards

Site and building planning must enable a school to deliver their curriculum and support their practices. Planning must consider a school's present and future educational needs that include the following elements: School Site Planning Priorities. Detailed Site Planning. Quality Access and Circulation. Accessibility. Pedestrian Access. Transport. Landscape Planning. Building Area in accordance with the educational client for area policies and definitions. Building Placement, Form and Envelope. Building Interior Planning Priorities. Building Circulation. Learning Spaces. Amenity Spaces. Site Infrastructure and Ancillary Buildings. Quality Outdoor Spaces. And Technical Standards for all these elements including safety, security, and environment [14].

The Five Elements of a Green Building Design

The followings are the key principles, strategies and technologies, which are associated with the five major elements of green building design: Sustainable Site Design; Water Conservation and Quality; Energy and Environment; Indoor Environmental Quality; and Conservation of Materials and Resources [15], [16].

Apply Six Themes in the Eco or Green School Program

In the eco or green school program, each school is recommended to apply six themes, these are Waste and litter, Water, Energy, School Grounds, Nature and Biodiversity and Climate Change. The Green school in Bali, Indonesia that was awarded the "Greenest School on Earth" in 2012 is an ideal example for the full application of these six themes [17].

The 10R principles of green design

The 10R principles of green design are Reduce, Reuse, Recycle, Renew, Recharge, Repair, Re-manufacture, Replace, Re-clear and remove. These are to be considered at the beginning of the design, because design is the source of all product production and use [16].

Green School Guidelines and Criteria

In US, most concerned Environmental Authorities agreed that to design and build a green school building and environment the following criteria are essential to be considered for developing the green school design guideline for present and future green school projects:

Indoor air quality. Thermal Comfort. Acoustic. Day lighting. Solar panels. Green roof. Water Efficiency. Energy Efficiency. Energy Efficient Lighting. Mold Prevention. Join Use of Facilities. Recycling. Low-Emitting Materials. Alternative Transport Option. Material Efficient. Easy to Maintain and Operate. Save and Secure. Building and its systems commissioning. Site Selection. Pollutant and Chemical Source Control. And Construction techniques [6].

2.1.3 Previous studies

A tremendous amount of knowledge and information were published on different aspects and subjects related to this study paper on sustainability of green school buildings and environment. These are summarized and tabulated hereunder in Tables 1, 2, and 3.

Table 1. Sources of Information and Data

No.	Type of Source of Information and Data	Examples of Source	References
01	International and National Conferences and Seminars particularly of the United Nations	United Nations	[19], [20]
02	Books	Eco-Schools Handbook - Denmark	[18].
03	Reports	The Australian Research Institute in Education for Sustainability (ARIES). 2021 Global Status Report for Buildings and Construction - Nairobi	[2], [3], [19], [20].
04	Research Papers and Articles	A Comparative Study of Green School Guidelines – Malaysia. Whole-building design for a green school building in Al-Ain, United Arab Emirates.	[1], [6], [8], [21].
05	Dissertations	Toward Sustainable School Design – Jordan.	[22].
06	Internet Websites	U.S. Green Building Council - https://www.usgbc.org/ Green Seal - https://greenseal.org/	[23], [24].
07	Agreements	Paris Agreement, United Nations – 2015	[25].
08	Standards	Designing Schools in Aotearoa New Zealand School Property Design Standards - Version 2.0, June 2022.	[14].
09	Codes	Green Building Manual (Law 212, 2019) – Green Building Code Bahrain. GSAS 2019 Design and Build Guidelines Manual for Building Typologies, Building Sustainably, Qatar	[5], [26], [27].
10	Rules and Regulations	Unified Guidebook of Building Permit Regulations – Chapter 17, Kingdom of Bahrain 1.3 – 2022	[28].

The above-mentioned types of sources for research studies on sustainable green buildings and schools cover the following tabulated areas in Table 2.

Table 2. Green Areas and Elements Categories

No.	Green Area and Elements Categories	References
01	Comparative studies and analysis	[6].
02	Benefits, Advantages and Disadvantages	[3], [4], [6].
03	Green Schools Attributes	[6], [13].
04	Green Schools Characteristics	[3], [4], [6], [22].
05	Statistics	[1], [4], [6], [13], [15], [16], [21].
06	Case Studies	[4], [8], [17], [22], [29], [46].
07	Update and improvement of Standards, Codes, Rules, Regulations and Policies.	[1], [2], [3], [5], [28], [30], [31].
08	Performance, Rating and Programs Criteria.	[6], [8], [10], [11], [13], [24], [32].
09	Innovation and Technology.	[15], [16].
10	Internal Air Quality	[33].
11	Cost and Life Cycle Costing	[13], [15], [16], [32], [34].
12	Designing Green Schools and Environment	[1], [21], [34].
13	Lessons learned	[8].
14	Green Schools Movement Around the World	[18].

Table 3. The Outcome Highlights of the discussion of the Reviewed Previous Studies

No.	Outcome Highlights	References
01	Clarifying and emphasizing the role of the Green Schools in the development of future education through building and environmental design changes and development that include the green characteristics of sustainable school buildings.	[19], [46].
02	Green Schools in comparison to traditional schools have shown that they improve student achievement, improve health and academic performance and decrease in absenteeism.	[19], [46].
03	Green School Initiatives in many countries including some Arab countries lead to sustainable development principles that promote the realization of the concept of sustainable development in addition to addressing global environmental challenges.	[19], [46].
04	Most previous studies have relied on one or more of the following research methods in their studies to achieve their goals: **descriptive approach, qualitative method,** descriptive analytical approach, associative descriptive approach, and the experimental approach.	[19], [46].
05	Stress the importance of the active role of the Green Schools in achieving sustainable development and strategies to improve the efficiency of the educational system and thus meet the needs of current and future generations.	[19], [46].
06	There is a severe lack of the Arab region studies in the field of Green School buildings and environment, in contrast to Foreign Studies, which are considered rich and broad in the field. The gap in the Arab theoretical literature, necessitating the need for additional research in this area. This gap reflects the Arab countries' low level of interest in this field, despite its enormous importance and impact. The gap covers **lack** of items such as: professional expertise and training, government support, availability of ecological materials, interest expressed by customers, national codes and regulations, integrated design for lifecycle management and green building technologies. In addition to stakeholder resistance to change, attitudes, culture, lifestyle and behaviors.	[19], [46].
07	There is a need to compare the Bahrain case study green school buildings actual performance in terms of energy, water and other resources expenditures, and students' performance to other government traditional schools to confirm that the green school's choice is an adequate decision.	[19], [46].
08	Educational Authorities in many countries are making serious efforts to improve school buildings to conform to green design standards of high efficiency through the application of some performance aspects and compliance with mandatory requirements, especially those that can be applied within the constraints of simple financial possibilities.	[19], [46].

The related knowledge within the reviewed previous research helped to go forward and build on to structure and develop this article, in a preliminary step to bridge the existing gap in the Arab theoretical research literature in this field. The outcome highlights of reviewing the previous studies are tabulated hereunder in Table 3.

3. Objectives and Research Hypothesis

3.1. Problem Statement

Public schools in the kingdom of Bahrain and other neighboring countries in the Arabian Gulf Region are facing poor and below comfort level indoor and outdoor environments due to the prevailing problem of harsh hot humid weather most of the year. This leads to high consumption of energy, particularly for air-conditioning, water and other resources due to the nature of the function of the schools and number of users. This makes running the school buildings adequately of high cost, uncomfortable and a challenge. Which necessitates effective actions to be taken to fill the gap, address the issues of the climate, environment and design challenges properly in parallel to optimized resources consumption.

3.2. Objectives

To achieve the aim of this article of sustaining green public-school buildings and maintain ideal and comfortable indoor and outdoor environments, taking into consideration the problem statement, main issues, and challenges above, the following objectives are set up and highlighted hereunder:

- To address harsh hot humid weather in Bahrain that prevails most of the year causing negative impact on school buildings and environment by establishing and developing a set of sustainable green design guidelines and green technology applications to improve air quality and maintain a proper building and environment temperatures. While optimizing and minimizing the use of natural resources at the time of construction as well as operation.
- To expose Bahrain experience in greening public-school buildings and environment as an example of the Arabian Gulf region. Interested concerned professionals in the field and educational authorities could benefit from the presented actual case study and lessons learned. In addition to contributing to reducing the lack of information in the field.

- To investigate that well designed green school buildings and their components can improve the indoor and outdoor school environmental qualities and have a positive impact on improving the school buildings and students rating performance. Also, fulfil effectively the strategies criteria of sustainable green design elements in future and existing schools.

3.3. Research Gap

The previous reviewed studies have shown an extensive development in the field of sustainable building and environment since the 1960s until today in many countries around the world, despite of these varying developments still there are many areas that can be further developed and improved to achieve sustainable green school buildings and environment. There is more than one previous study, including one issued recently in April 2023 under the title of "Evaluation of Green Schools Design Using the UN Schools as an Example" [19]**,** [46] showed that there is a severe lack of the Arab region studies in the field. This Gap covers lack of items mentioned in Table 03: Sr. No. 06 - Outcome Highlights (starting from: Lack of professional expertise and training). This confirms the existence of a gap in the Arab theoretical literature, necessitating the need for additional research in this area, due to its enormous importance and impact. Some of the previous studies showed that the magnitude of challenges and changes necessitate rethinking strategies to improve the efficiency of the present educational systems, in parallel of improving the efficiency of the green educational buildings and environment [19]**,** [46]. More comparative studies and investigation are required between various solutions of green and traditional schools regarding each element cost and function, performance of building, environment and students. This will give insight into the educational authorities to have more options for decision-making.

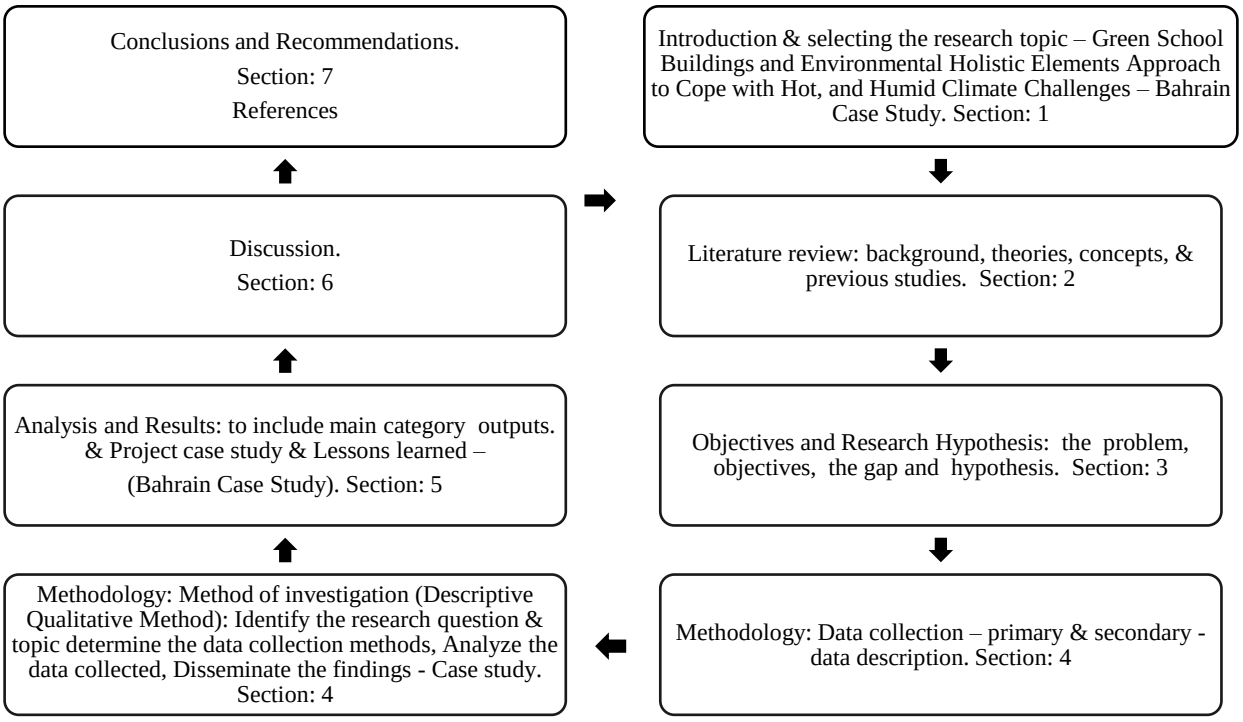
3.4. Research Hypothesis

Taking into considerations the above-mentioned objectives, the gap items and the related literature reviewed to support this article hypothesis, the following three hypotheses are proposed for conducting this research article:

- Developing, establishing, and updating dynamically and systematically a set of green design guidelines for sustainable green school buildings, their elements and environment will improve air quality, create continuous comfortable climate, and weather indoor and

outdoor environments while optimizing the use of natural resources at the time of construction as well as operation.

- Publishing case studies and lessons learned will help in creating knowledge and data that are more available and beneficial to concerned professionals in the field of green school buildings and environment, in addition to concerned educational authorities.
- Sustainability of green school buildings and environment will improve the performance of school buildings, their surrounding environment and students, and ultimately upgrade the life quality based on recognized performance criteria programs.



(For more details on each stage please refer to the related section – in the Article)

Figure 1. Schematic Diagram Displaying Stages of Research Process

4. Methodology

4.1. Data Collection

The data collection for the purpose of this research article relied on most of the relevant sources that cover available literature, online interviews, and interactions with architectural and building consultants, environmental and educational authorities above-mentioned under Section 2-

Literature review to find answers and solutions to the research problem and gap, test the hypothesis and evaluate the outcomes. The data collection methods adopted here are of two categories: primary and secondary methods of data collection. The Primary data collection [47], [48] is the process of gathering data directly from a first-hand original source and expected to be used by the researcher him/herself or the organization who originated, collected and archived them. Methods to collect Primary data include surveys, interviews, observation, field notes from focus groups, documents and reports, archival records, physical artifacts, and photos. Primary data collection has several advantages over other forms of data collection: Primary data is more accurate and reliable because it comes from a direct source. It is faster and easier to collect primary data than secondary data. The Primary data collection method is more adequate for projects case studies as the information is gathered directly from the original source. The Secondary Data Collection Method [47], [48] is the process of gathering and compiling existing data sourced from a variety of channels such as data that has already been published in books, journals, online portals, literature, online interviews, and interactions with architectural and building consultants, environmental and educational authorities. For this article selective published reliable literature and secondary data were considered and reviewed under a set of criteria for selection such as date of publication, credential of the author, reliability of the source, quality of discussions, depth of analyses, and the extent of contribution of the text to the development of the research area.

Secondary data collection has several advantages such as volume where thousands of published resources are available, speed, low cost, ease of use, and ease of access particularly to the internet at little or no cost.

4.2. Primary Data Collection

The primary data collection is important for creating evident type case studies that are based on experienced, valid and reliable facts such as First Bahrain Green School Case Study [36]**.** The data collected for this article and the Bahrain Case study are from the Ministry of Works Projects Data Base accumulated data on each building project handled by the Construction Projects Directorate of the Ministry. Each building project, through its life cycle from its initiation until the completion of closeout has an integrated comprehensive folder under which there are subfolders and files on all phases of the project and their elements. These are electronically fed and archived instantaneously on the Data Base of each project. Each project's primary data on the Data Base

covers the following items: Introduction and Background. Brief and Requirements. Description and objective. Location and Site. Drawings and Specifications. Green Features. Design for accessibility. Green Building Design Guidelines. Lesson Learned. Any required primary data or information can be retrieved and generated from the Ministry Data Base by authorized staff depending on their authority level to obtain data of different importance and sensitivity level.

4.3. Secondary Data Collection

The secondary data collection could be obtained from sources of existing databases and archives, internet, libraries, literature, experts and concerned consultants. In this article, the secondary data collection is essential and important to get valid, reliable information to address various issues stated above under the problem statement and the research gap such as the climate, weather, environmental, emissions, school buildings green design and performance challenges, that lead to achieve the article objectives and ultimately its aim. Therefore, these secondary data cover the following reviewed areas: Updated Standards, Codes, Rules and Regulations. Performance, Rating and Programs. Innovation and Technology. Statistics. Internal Air Quality. Cost and Life Cycle Costing. Designing Criteria and Principals of Green Schools. Green Schools Movement around the World. Lesson learned. Advantages and Disadvantages. Green Schools Characteristics and Attributes. Strategies and Initiatives. Comparative Studies and Analysis. The Role of Architects, Other Concerned Designers and Professionals, Urban, Environmental and Educational Authorities in Addition to Political Decision Makers [36]. These reviewed areas of the secondary data could reveal new potential sustainable solutions to greening school buildings and play a vital role in the students' quality of education, health and wellbeing. Furthermore, the information gathered and reviewed will allow analyzing present and past strategies on green school buildings and the environment while stay informed on what needs to change.

4.4. Data Description

This research study relied on well-recognized national and international sources to support the quality of the research and the ultimate outcomes. The reviewed information and data are characterized with attributes and criteria that are mentioned above under Section 2- Literature review - 2.1.2 Concepts related to indoor air quality, thermal comfort, acoustic, day lighting, Solar

panels, green roof, water efficiency, energy efficiency, recycling, low-emitting materials, and easy effective maintenance and operation. These attributes could be measured and rated as per recognized tools to give the performance level of both the school buildings, and their students' educational output scores and behavior. This indicates the level of achievement concerning green sustainability, comfortability, healthy and safe school buildings and environment. The analysis of the classification and tabulation of the reviewed data is expected to reveal suitable solutions and guidance to address arising issues and topics concerning rethinking designs and modifications of sustainable green school buildings, specifications, improving the conditions of the contracts, energy development and practices, updating Codes, Standards and Building Rules and Regulations. Addressing such issues will be characterized by a holistic elements approach to cope with various arising challenges.

4.5. Method of investigation: Descriptive Qualitative Method

The nature of this research article being of multidiscipline data and information requirements of selective published reliable literature for exploring prior research that could help in designing creative sustainable public schools in an integrated and comprehensive manner. This necessitates the adoption of the Descriptive Qualitative Method [49], [50], [51] that involves rich collection of data from various mentioned sources to research the hypotheses stated in this article and address the stated problem and gaps to ensure that the resulting outputs in terms of guidelines and other suggestions are valid and reliable. Conducting the Descriptive Qualitative Research Method entails the following steps:

Step 1. Identify the research question or topic of interest: Public schools in Bahrain and in the Arabian Gulf Region are facing poor indoor and outdoor environments due to the prevailing bad weather challenges most of the year. Which necessitates effective actions to be taken to address the identified issues.

Step 2. The next step is to determine the data collection method or methods that will be used: The data collection methods adopted here are primary and secondary methods of data collection as explained above under Data Collection. These adopted data collection methods are selected to ensure that the issues and challenges are addressed, and the objectives are met through their ability to provide rich and detailed information about Sustainable Green School Buildings and Environment.

Step 3. Analyze the data collected: Once the data has been collected and reviewed, the next step is to analyze it. The goal of the analysis is to develop a rich and detailed understanding of the Sustainability of Green School Buildings and Environment under this study. Doing so allows further research to be developed for best policies and/or practices in the field of sustainability, green buildings and the environment. Analysis may involve coding the data into categories or themes or using other analytical techniques to identify patterns and relationships within the data. In this article the reviewed literature covering both primary and secondary data are systematically identified, classified, categorized, tabulated, and finally summarized in an organized manner to include the following main categories: Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions, and Innovation [10]**,** [11]**,** [13]. Correlation needs to be established between the proposed hypotheses and the output categorized data that significantly support them.

Step 4. Disseminate the findings: Finally, the results of the descriptive qualitative research should be communicated to others.

In conclusion, descriptive qualitative method is a valuable tool for exploring the characteristics and qualities of a research topic. In this article, it allows capturing the complexity and richness of the subject and provides a detailed understanding of its context, history, sustainability, green design elements, environmental, climate, economical and natural resources, and behavior and cultural significance.

4.6. Case Study

A main part of the methodology of this article is to present Bahrain experience in greening public-school buildings and surrounding environment in the form of a case study for the first public green school including lesson learned, giving the opportunity to others in the Arabian Gulf region and elsewhere to benefit from the case study published information [35]**,** [46]. The detailed main Case study and Lessons learned are presented separately under Section: 5.2 Results: (9- Bahrain Case Study and Lessons learned) due to their importance in contributing to greening school buildings. Quoted other parts of case study examples are pointed out under Section: 5.2 Results: (7- Innovation and technology) concentrating on innovative green initiatives and ideas adopted in some schools around the world and could be applied to other schools elsewhere.

5. Analysis and Results

5.1. Analysis

Sustainability and greening of school buildings and environment is a complex topic with many issues to be addressed. Such complexity involves an input of huge data collection of varying nature and disciplines that need to be sorted out to create useful patterns, relationships and links, in addition to correlate between each of the proposed hypotheses and the result outputs that significantly support their applicability. Emerged sorted out categorized areas can be referred above to both primary and secondary data [38]**.** The reviewed areas of the secondary data revealed potential sustainable solutions to greening school buildings and environment, in addition to improving students' performance, health and wellbeing.

From the early emergence of the concept of green buildings in 1960s, there was a continuous development of establishing guidelines, codes, and standards in field of sustainable buildings with special focus on schools and alike buildings. These were established and still being developed by recognized authorized organizations such as professional bodies and institutions, research institutions and individual researchers, and Government concerned authorities [5], [26]**,** [27], [28]. These technical documents played a vital role in helping and guiding professionals to provide green design solutions to various elements within school buildings and environment. Such design solutions were reflected in many published research papers, case studies and lessons learned. Moreover, implementation of the contents of these standards, codes and guidelines showed a significant positive impact on the performance of the school buildings as well as their students. Lessons learned are a very useful source of feedback to regularly improve and update these standards and guidelines. Accordingly, in this article a summary of proposed guidelines is introduced under Section 5.2 - The Results: 4 - Green school buildings and environment design guidelines. The latest Construction Projects Green Buildings Design Guidelines Titles are highlighted under the Main Case Study – Bahrain. The Application of the Guidelines themselves has a great positive impact on the first Bahrain Green School Buildings as indicated in the Main Case Study. Also, these helped and contributed to formulating the suggested guidelines under Section 5.2 - The Results 4 - Green school buildings and environment design guidelines.

Analyzing the categorized output data requires focusing on addressing the root causes for the identified broad collective challenges of uncomfortable weather, climate, and environment, in

addition to school buildings design flaws and high resources consumption. Adopting the qualitative descriptive method that illustrated above for data analysis showed a great significance in exploring best policies, practices, new green technology and innovative ideas in the field of sustainability, green buildings and environment through the various categorized outputs. These include, Improve Indoor Environment Quality, Save Energy, Transport, Save Water, Maximize the Use of Recycled Materials, Land Use and Ecology, Reduce Emissions, Green Innovation, Management of Commissioning, Building Guide, Environmental, Waste, Learning Resource, Maximize the use of natural lighting and Maintainability. Consideration of all these outputs in greening school buildings could support multiple further improvements to strategic initiatives. Despite what has been achieved of development in this field, still there are many areas that can be further improved to cope with the gap by keep staying informed and alert on what needs to change, in terms of actions suggested hereunder:

- Enhance and develop architectural school buildings planning, design and environment through their complete life cycle to achieve high sustainable green projects [43].
- Enhance, develop and update unified criteria to the various existing green school guidelines and codes to cover all required concerned aspects.
- There is a need to create and design more appropriate research studies involving the adoption of suitable programing and application systems to overcome confounding factors.
- Greater emphasis to be focused on cleaning, care taking, operations and maintenance practices of green school guidelines to continuously maintain a high-performance integrated school buildings and environment by specifying quality building systems.
- The result of the analysis of the categorized and sorted out information concerning most important areas and aspects showed that these could play a vital role in enhancing and promoting the outcome solutions for achieving sustainable public schools. The outcomes can be summarized in the following main categorized title topics that will be elaborated and highlighted in the results:

    - General characteristics of public green school buildings
    - Advantages and benefits of public green school buildings
    - Disadvantages of public green school buildings
    - Green school buildings and environment design guidelines

- Green Building Councils influencing school buildings
- Performance measuring and rating tools for school green buildings
- Innovation and technology
- Significant statistics outputs
- Case study and Lesson learned.

5.2. The Results

The outcome results of the analysis concerning the main theme of this study are discussed and elaborated hereunder for each outcome topic of Section 5.1 (Analysis):

5.2.1 General characteristics of public sustainable green school buildings

Establishing the general characteristics of sustainable green school buildings is important to develop and build a sustainable school design. The Centre of Green School under the U.S. Green Building Council emphasized this aspect of the sustainable green school characteristics as green, healthy, and high-performance schools provide many benefits for students, teachers, parents and the community, including the following: [4], [22], [39], [40].

- Provide A Unique Educational Opportunity: Buildings can become teaching tools and important features of science, mathematics, and environmental curriculum when green features, advanced technology, and design in schools are used to excite kids about learning real world applications of green technologies [40].
- Create Green Jobs: Investing in construction of green schools is an investment in green jobs, including green building product manufacturing.
- Protect Health: Schools built with more daylighting, improve indoor air quality and ventilation, and healthy green building materials, like non-VOC (Volatile Organic Compounds) carpets and paints, are healthier for students and staff.
- Increase Student Performance: Studies have shown that student performance can improve up to 20% when they learn in green classrooms that have protection's health features.
- Conserve energy and natural resources: Operating costs for energy and water in a green school can be reduced by 20% to 40%.
- Reduce Carbon Emissions: Green schools significantly reduce carbon dioxide emissions (i.e. Building 34 new green schools in Los Angeles alone would reduce 94,000 tons of CO2).
- Reduce Water Usage: On average, a green school reduces water usage by 32%.

- Improve Daily Attendance: Students in green schools are absent less frequently. By reducing absenteeism just 15%, a typical elementary school would save $40,000 to $60,000.
- Improve Equity: Greening public schools creates an opportunity to improve the health and educational settings for all students, while considering students' diverse identities and needs.
- Others Related Characteristics**:** Promote natural environment and habitats protection.

Encourage recycling and reuse. Reduced demand for local landfills. And encourage waste management efforts to benefit the local community and region.

5.2.2 Advantages and benefits of public green school buildings

Public green school buildings have many benefits on the environmental, economic, financial, and social levels, and have a great impact on students and teacher's lifestyle. The U.S. Green Building Council researched the benefits of sustainable green schools; these benefits were broad, ranging from the impact on student health, test scores, and teacher retention to reduce operational costs. The advantages of public green school buildings are summarized hereunder: [3]**,** [4]**,** [6]**,** [42]**.**

Costing: Mostly, the initial construction costs of a green school building are like the conventional standard school building and sometimes they cost a little bit more as they require special materials and systems to be built. But when comparing the life cycle costing of each of them, reviewed research reports showed that green school's cost less than 2% of conventional schools in US [13]**,** [15]**,** [16]**,** [19]**,** [32]**,** [34]**,** [41]**.**

Efficiency: covers three aspects, the first is Energy**:** Green schools use an average of 33% less energy than conventionally designed schools, due to efficient lighting, greater use of daylighting and sensors, and better insulated walls and roofs. The second is Water**:** According to U.S. National Research Council, green school design had estimated an average water use reduction of 32%. And the third is Materials**:** Green buildings are built from natural, non-toxic, eco-friendly and recycled materials [42].

Preserving infrastructure: Being efficient in both energy and water supply, these buildings stretch the capacity of local infrastructure greatly.

A teaching tool: The green school itself serves as a teaching tool, demonstrating to students, faculty, and parent's practical ways on how it can turn back the clock on global warming while creating healthier, more efficient, and less costly learning environments.

5.2.3 Disadvantages of public green school buildings

The disadvantages may include the followings: 1- Difficulty of Buildings Location [42]. 2- Availability of Green materials. 3- No air-cooling features (i.e. requirement for air conditioners systems). 4- Longer time to construct. 5- The initial cost of construction [42].

5.2.4 Green school buildings and environment design guidelines

One of the main outcomes that can contribute significantly to a successful sustainable green school building and environmental is Design Guidelines as these are the outcome of valid applicable experience. These guidelines are formulated so they can be adopted in a varying applicable model taking into consideration the reviewed literature particularly of the United Nation Schools in the Middle East including their green design guidelines, other considerations, criteria, updated standards and codes rules and regulations and updated green building policies. Green school buildings and environment guidelines could differ for each authority within the same country to cope with specific requirements and criteria in order to achieve target outputs that enhance the performance. Guidelines are an important tool to fulfil specific green objectives and to overcome rising issues and challenges concerning various school building elements and environment [3], [7], [16], [19], [33], [34], [41]. As a result of investigating literature review concerning green school buildings and environment a set of proposed Guidelines is formulated hereunder to help both interested professionals in the field and concerned Educational Authorities for achieving better and adequate design solutions:

Site planning: It is important to focus on enhancing the site's personality, working within the constraints and opportunities of the existing site and treat the site organization as a strategic issue. The way leading to, and the school entrance are to be appealing, inspiring and welcoming [7]. The site planning and locating school buildings on a green site will minimize environmental impact and make the most of available natural light, solar radiation, and shadow casting. And the site of the school to be selected within a public transportation network where it is fast and easy to reach to various required locations to minimize pollution.

The passive design: The passive design concept is emphasized in the search for conducive and comfortable learning and teaching environment. Building orientation is considered to avoid overexposure to heat and sun through application simulation program for locating the best orientation, and distribution of various blocks and other related elements [7]**.**

Designing Passively: One strategy for achieving green and sustainable design is to use passive design features. Proper building positioning based on sun orientation will cast a shadow in the area where students usually gather for their assemblies and activities during rest periods. Create appropriate design components that respond to harsh hot and humid climate (i.e. In Bahrain) such as shadow, solar radiation, daylighting and other green technology innovations [7]**.**

Ease of movement: Ease of movement safely within the school inside and outside the buildings is an essential part of the students' activities while being at school by providing spacious corridors, walkways, improved circulation, social spaces, directions signs, and attractive external spaces [7]**.**

Buildings: The following architectural and engineering design considerations regarding school buildings and surroundings need to be applied as deemed correctly suitable: [7]

- Adopt a unified design concept that connects all contract documents in a dynamic integrated manner.
- Design a form and massing suitable to the site and the surrounding environment.
- Design effective massing that is well proportioned in terms of internal and external spaces.
- Treat the elevations to reflect the design concept for inspiring structural and architectural unique creative elevations.
- Ensure that the selected materials, fabric, and the envelope are long lasting, simple to maintain and clean, and have a positive impact on the scheme's quality.
- Selecting green renewable materials that are non-toxic, biodegradable where applicable, and easily recycled and reused effectively.
- Designing energy, lighting and other electrical systems by maximizing the use of renewable resources thus conserving fossil fuels and minimizing gas emissions.
- To integrate the indoor and outdoor plumbing systems, with and complement the irrigation systems to conserve water.
- Designing an indoor environment that provides occupants with a comfortable temperature, the required air quality, lighting, and acoustics.

Analysis of Solar Radiation: Most simulation ecological software for eco-school building's solar radiation analysis revealed that a majority of the roof was the most exposed area to direct sunlight, in addition to open areas around buildings with an average daily radiation of more

than 6kwh/m2 [7]. The analysis showed that solar photovoltaic panels work best on the roof, and for creating sheltered: parking areas, recreational and rest areas for the users.

Analysis of Daylighting and Windows: A recent study showed that the open spaces between the school blocks received nearly 70% of the natural lighting in the area; accordingly, there is no requirement for artificial lighting for reading. High-performance, low emissivity glazed windows will minimize heating demand while reducing solar heat gains to reduce cooling demand, without minimizing the amount of light that enters the building. High-performance sensors are used to adjust artificial lighting based on the amount of sunlight available [7].

Photovoltaic (PV) Solar Panel with Green Technology: The same recent study mentioned above showed that the proposed design was inspired by the position of the sun. The roofs of each block are oriented more toward the south to maximize sun exposure hours provided no obstacles in the way to the PV panels to generate more electrical energy [7].

5.2.5 Green Building Councils influencing school buildings:

The World Green Building Council (GBCs) is a network of national green building councils in more than 90 countries around the world, making it the largest international organization influencing the green building marketplace. GBCs mission is to facilitate the global transformation of the building industry towards sustainability through market driven mechanisms and adoption of green building practices. GBCs are promoting greening schools through environmental sustainability rating tools, green building education resources and the incorporation of sustainability concepts into school curricula. Today, GBCs around the globe are actively raising standards for better-designed greener schools that improve the health and learning of the students while optimizing resources utilization efficiently. The U.S. Green Building Council (USGBC) went a positive step further by establishing the Center for Green Schools in 2010 to help focus its green school efforts and affect change for this critical building type that no other buildings speak more to the power of green building than the places where our children learn. The Center sees an opportunity to educate a new generation of leaders capable of driving global market transformation. High-performing schools could result in high-performing students as green schools go far beyond bricks and mortar [7], [43], [44].

5.2.6 Performance measuring and rating tools for green school buildings

Many public and private consultants around the world adopt different third-party certification

programs such as LEED, and BREEAM, to evaluate the performance of green building projects sustainability based on specific recognized criteria. In parallel, many countries established their own organization for assessing the environmental attributes of new and refurbished education facilities through performance green school rating systems. The green schools rating tools can be used to rate the environmental merits of an education facility through its life span. Two examples of Rating Tools to assess the performance of the entire School buildings are listed below [7], [43], [44].

US Florida Department of Environmental Protection: under the Florida Green School Designation Program environmental guidelines allow primary and secondary schools to evaluate operations, set goals and take specific actions to continuously improve environmental performance through a set of Best Management Practices. To become designated, schools must conduct a specified number of environmental practices in five areas of sustainable operations: Communication and Education. Waste Reduction, Reuse and Recycling. Water Conservation. Energy Efficiency. And Air Quality. The rating program is titled as "Apple Levels" [44] for which the requirements are as follow: Green Apple Schools must implement at least 17 initiatives; Bronze, Silver, and Gold Apple Schools must complete the Tiered-Designation Application and achieve between 208 and 394 points, 395 and 478 points, and 479 and 557 points respectively; The Designation Period is valid for three years from date of issuance, and need to be renewed. In addition to on-site visits and to submit required performance data annually [7], [43], [44].

The Green Building Council of Australia (GBCA): promotes green building programs, technologies, design practices and processes, and operates Australia's only national voluntary comprehensive environmental rating system for Buildings:

G*reen Star Rating:* Four (score 45-59), Five (score 60-74), and Six Stars (score 75-100) for Best Practice, Australian Excellence, and World Leadership respectively.

An additional rating system was released in 2008 specifically for School Buildings. The rating tool is "The Green Star – Education v1" for assessing the environmental attributes of new and refurbished education facilities in Australia.

The Green Star – Education v1 Rating: consists of the following categories and credits (Category Weightings): Management 10%. Indoor Environment Quality 20%. Energy 25%.

Transport 10%. Water 15%. Materials 10%. Land Use and Ecology 5%. Emissions 5%. The total of the eight categories is 100%. One more category is innovation without mentioning its weight as this could vary from project to another depending on its nature. Credits are awarded within each of the categories based on the building's environmental merits in a range of areas [7], [10], [11], [12], [13], [43].

5.2.7 Innovation and technology:

Sustainable construction technologies used in green construction include: Biodegradable materials. Solar power for heating, ventilation, and air conditioning. Green insulation. Lighting. Smart appliances. Cool roofs. Sustainable resource sourcing. Low-energy school and zero-energy building design. Water efficiency technologies. Electrochromic smart glass. Self-powered buildings.

Examples of innovation and technology applications from green schools case studies around the world:

- Ion Neculce High-School Bucharest, Romania: Voice clarity and absorption are achieved through a combination of ecological materials and scientific design. New ceiling tiles of 70% recycled glass and a plant-based binder were installed for the school's larger laboratory ceiling.
- Rochester School Chia, Colombia**:** Several green initiatives have been included in the design. Solar collectors and electric heat pumps are used to heat the school's swimming pools and dressing rooms. 12 % of the electricity demands of the campus are provided by a 20kWp solar photovoltaic array. Potable water consumption has reduced by 35%, through water treatment plant, which provides tertiary treatment for wastewater. This treated water is recycled for toilet flushing and irrigation. Within classrooms, acoustics and lighting are automatically monitored and controlled.
- 3-Kimi Ora School Wellington, New Zealand: is a special needs school that caters for a diverse range of students aged from five to twenty-one years of age. The school was the first education building to obtain both a five Green Star Education Design and Built certified rating in New Zealand. The Innovation Salient features are designed to reduce greenhouse gas emissions in operation by more than 75% compared to a typical school. The indoor environmental quality is improved using low Volatile Organic Compounds paints and mixed mode ventilation. Natural lighting is maximized with over 90% of the school's area within 8 meters of an external view. The building is constructed from 100% recycled steel: with over 50% Forest Stewardship Council (FSC) certified timber and locally sourced landscaping materials. Fresh drinking water is conserved, and storm water runoff is reduced using rainwater collection and water efficient fittings. Innovation points were awarded to the school for the numerous building attributes that functioned as learning resources.

5.2.8 Significant Statistics Records:

Significant Statistics records are included in this research to assist concerned authorities in their decision to adopt greening school buildings as a desirable option to overcome serious challenges influencing environment and our life quality (i.e. wellbeing, productivity and performance):

The Greening America's Schools: Costs and Benefits [4]**,** [7]**,** [43] study recorded the following results:

- There is 41.5 per cent improvement in the health of student and teachers (such as reduced incidence of asthma, flu, respiratory problems and headaches)
- Up to 15 per cent improvement in student learning and productivity
- Up to 25 per cent improvement on test scores due to good lighting and ventilation.

A UK study [4] found that school layouts could influence a child's development by as much as 25 percent, positively or negatively. The study identified six classroom design factors: colour, choice, connection, complexity, flexibility and light that are clearly correlated with grade scores.

A US study on Daylighting by The Heschong Mahone found that there is a dramatic correlation between day lit school environments and student performance, including: [4]**,** [45]**.**

- 20 % faster progression in mathematics
- 26 % faster progression in reading.
- Increased performance of 5 to 10 % when students had window views.

More than one Green School study showed that Green Schools could contribute up to a 15% decrease in absenteeism [19].

A study revealed that environmental factors have affected 73% of the score in the students' performance [21].

5.2.9 Case study:

Project history: It is the first public green school at the kingdom of Bahrain, its name is "Girls Primary/Intermediate School at Wadi Al-Sail - West Riffa, Bahrain". This green school was completed in 2016, after which many schools were built on a similar track. The main intention of this case study is to present Bahrain experience in this field that could be compared to other reviewed schools case studies elsewhere, as each case study is

unique from which lesson learned could be drawn. Also, this case study can be considered a step forward in filling the gap due to lack of the Arab region studies in the field of green schools. Figure (2) shows the location and site plan of the school in Bahrain.

Project Descriptions: This Girls Primary/Intermediate School is located at Wadi Al-Sail of West Riffa city. The client is the Ministry of Education. The plot and built-up areas are 28 673 M^2 and 16 626 M^2 respectively. The contract sum is about $ 10.0 Million. The Construction

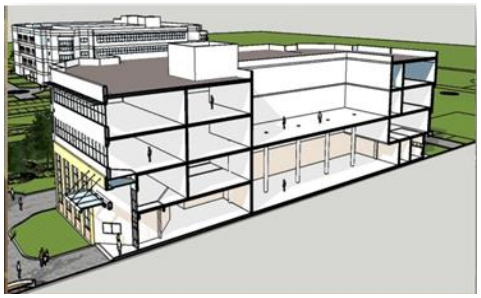
Figure 2. Location cum Site Plan
Source: Ministry of Works -Bah.

Figure 3. Perspective and Under Construction Views
Source: Ministry of Works – Bahrain.

Contract Period is 18 months starting from 1st October 2013. The school has four floors (Figure 3). The main components are 38 classrooms. Multi-purpose hall. Administration. Science, Domestic and Computer laboratories. External works, sub-station, guard room, boundary walls and associated services. The design occupancy is 1533 person.

Project Objective: The objective of the project is to design and construct a new type design **(**incorporating best green buildings practices) for Girls Primary and Intermediate School to fulfill the new requirements of Ministry of Education. The design must be a modern single building complex with a central air-conditioning system, provisions for high quality finishes, mechanical/electrical and information technology services.

Design Concept: Figures (4), (5), (6), (7), (8), (9), (10), and (11) The main concept focuses on providing students with sufficient common areas for their interactions and activities within a controlled sustainable green environment. The Multipurpose Hall is centrally located to serve as the heart of the school and to allow for more generous and dynamic spaces for the students. The main vertical circulation for the school is centrally located with provision of four big size elevators



Figures 4. Pictorial Section Through the Main Building
Source: Ministry of Works

supported with large lobbies at every floor, in addition to four semi-circular shape staircases located at four corners of the building.

Figure 5. General Perspective View
Source: Ministry of Works

Figures 6 and 7. Front Elevation of the Main Building (Main Entrance and Shading Elements)
Source: Ministry of Works

Figure 8. Left & Rear Elevations
Source: Ministry of Works

Figure 9. Right Elevation
Source: Ministry of Works

GROUND FLOOR PLAN

ROOM DESCRIPTION

Reception	1
Head Master	1
Secretary	1
HM Meeting Room	1
Registration room	1
Training/Meeting Room	1
First Aid Rooms	2
Administration Office	1
Family Education Labs	2
Science Labs	2
Typing & Photocopy	1
Store	1
Music Room	1
Strong Room	1
Scout Room	1
Furniture Room	1
Sports Teacher Room	1
Changing Rooms	2
Students Toilets	2
Canteen	1
MultiPurpose Hall	1
AHU Rooms	5
Server Rooms	2
Electrical Rooms	2
Telephone Room	1

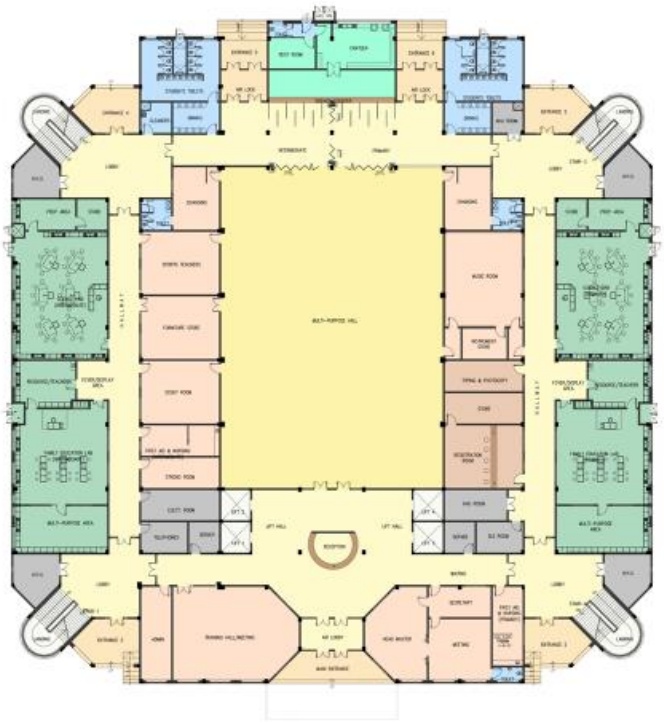


Figure 10. Ground Floor Plan
Source: Ministry of Works

SECOND FLOOR PLAN

ROOM DESCRIPTION

Technology Labs	2
Special Need	3
Art Rooms	2
Social Programming	3
Learning Tech Specialist	1
Supervisor Rooms	2
Social Advisor	1
English Club	1
Classrooms (Primary)	9
Classrooms (Inter)	4
Store	2
Students Toilets	2
Staffs' Toilets	1
AHU Rooms	5
Server Rooms	2
Electrical /Tel Rooms	2

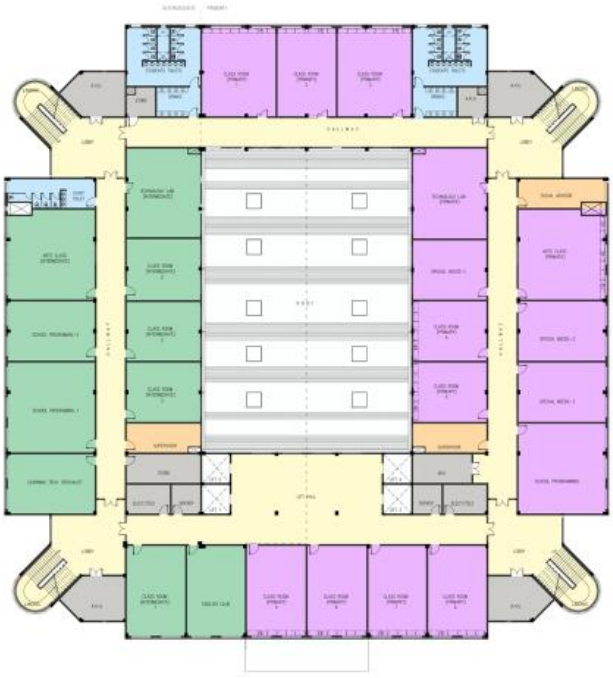
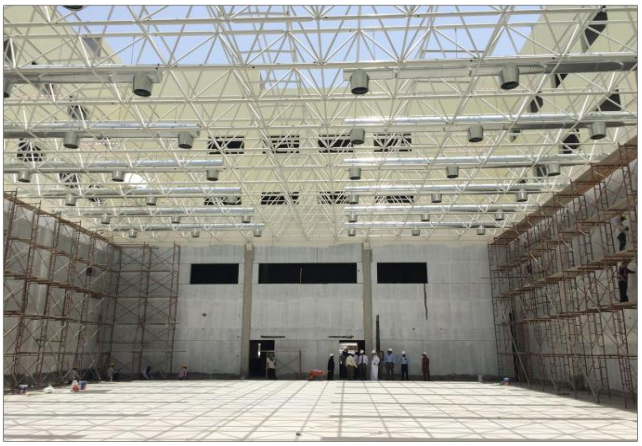


Figure 11. Second Floor Plan
Source: Ministry of Works



Figures 12. Multipurpose Hall (Ceiling/Services) Before Roofing
Source: Ministry of Works

Figures 13. Multipurpose Hall (Ceiling/ Services) After Completion
Source: Ministry of Works

5.2.10 Construction Projects Green Buildings Design Guidelines Checklist - Bahrain:

The applicable existing Green Buildings Design Guidelines Checklist is outlined hereunder. These are initiated in May 2011, and have been developed until what they have reached today reflecting the latest development in the field of guidance to greening school buildings and environment. These were produced, developed and being adopted by Construction Projects Directorate of the Ministry of Works for public building projects including the first public green school at the kingdom of Bahrain which is the concern of this article case study. The guidelines titles include the followings:

Urban Context: Load on Local Traffic Conditions, Pedestrian Pathways, Proximity to Amenities, Light Pollution, Noise Pollution, Public and Private Transportation, Sewer and Waterway Contamination, Shading of Adjacent Properties.

***Site*:** Ecological Value of Land, Vegetation and Shading, Desertification, Rainwater Runoff, Mixed Use, Heat Island Effect, Adverse Wind Conditions, Acoustic Conditions, Landscape Management.

Energy: Energy Demand and Delivery Performance, Fossil Fuel Conservation, Emissions: Carbon Dioxide, Nitrogen Oxides, Sulfur oxide, and Particulate Matter.

Water: Water Consumption

Materials: Regional Materials, Responsible Sourcing of Materials, Structure Reuse: On-site, Materials Reuse: Off-site, Recycled Materials, Design for Disassembly, Life Cycle Assessment.

Indoor Environment: Thermal Comfort, Low-Emitting Materials, Natural and Mechanical Ventilation, Indoor Chemical and Pollutant Source Control, Views, Glare Control, Illumination Levels, Acoustic Quality, Daylight.

Cultural and Economic Value: Heritage and Cultural Identity Support of National Economy.

Management and Operations: Commissioning Plan, Energy Use Sub-metering,

Leak Detection, Organic Waste Management, Recycling Management, Intelligent Building Control System**.**

5.2.11 Green Characteristics and Features:

The followings are some of the green characteristics and features incorporated into the design of the case study school based on Ministry of Finance Eco Friendly, Ministry of Works Green Building requirements, and the educational requirements of the Ministry of Education:

External Thermal Roof Insulation: The roofs for the academic blocks are made of precast roof slabs finished with insulated materials as approved by Electricity and Water Authority. It improves energy efficiency and effective thermal resistance with u-value of 0.447 W/m^2. °C., compared with required value of not more than 0.6 W/m^2. °C. The roof for the Multipurpose Hall is made of composite panel of excellent thermal performance with u-value of 0.4 W/m^2.°C. Figures (12) & (13).

Thermal Wall Insulation: Figure (14) The use of 200mm thick Insulated Concrete Blocks with Slotted Polystyrene for external walls reduces heat loss during winter and minimizes heat gain during summer. The u-value for the wall is 0.568 W/m^2.°C., compared with required value of not more than 0.75 W/m^2. °C.

Figure 14. Thermal Insulation Concrete Block

Source: Ministry of Works

Energy Saving Windows: All windows and curtain walls are of Energy Efficient Windows with Double Insulated and Tinted Glass with u-value as low as 1.80 W/m^2.°C.

Central Air Conditioning: The school is provided with a high-performance Heating, Ventilation, and Air conditioning System, that makes considerable energy saving due to High Energy Efficiency Ratio of 6.5 or more, Energy Recovery Ventilator, High Efficiency Filter, Dual Fan with Double Speed Operation and Building Management System.

Energy Saving Lights: All internal and external light bulbs are either Light Emitting Diodes or compact fluorescent light energy saving lamps. Dimmable low energy consumption lights are used at the Multipurpose and Sports Hall. In addition to programmable automatic lighting control system introduced, using occupancy sensors, and light level sensors to dim the light to a pre-set illumination level. These are integrated with the level of Daylight and controlled by programmable Solar Digital Timer.

Solar Water Heater: Solar water heaters as a renewable energy for water heating system.

Water Recycling: Wastewater that is produced from Reverse Osmosis Plant and condensing water from air conditioning units will be used for irrigation.

Design for Water Efficiency: The use of water efficient fittings such as Water Efficient Flushing System for water closet Dual-flush toilets that use 1.6 gallons per flush for solid waste removal and 0.8 to 1.2 gallons for liquid waste. Self-closing Delay taps for drinking areas with flow limiter 7.5 liter/min. Installation of Angle Valve in each sanitary ware water connection to optimize the flow to minimum.

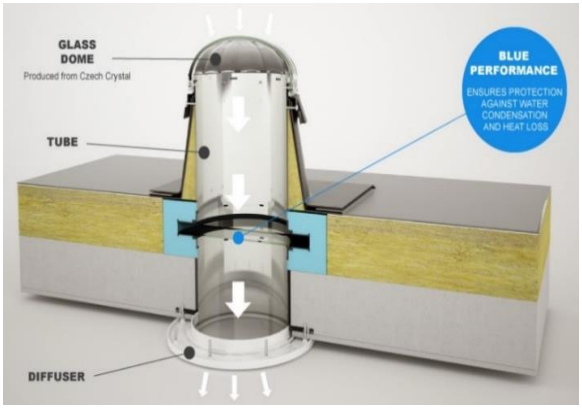
Design for Healthier and Better Indoor Environmental Quality: All classrooms, corridors and Multipurpose Hall are acoustically insulated, to reduce the noise pollution to a Noise Reduction Coefficient below 0.70, by using 4mm thick acoustic vinyl flooring with acoustic properties of 19dB, acoustic ceiling tiles of 600mm x 600mm high quality reinforced perforated gypsum ceiling and using of double-glazing windows and curtain walls to reduce noise levels to 35 decibels. In addition to use of air-conditioning systems of less than 35 Noise Coefficient.

Environmentally Friendly Materials and Resources: Some of the materials used for the school are 100% Recyclable materials such as vinyl flooring for internal spaces and ceiling

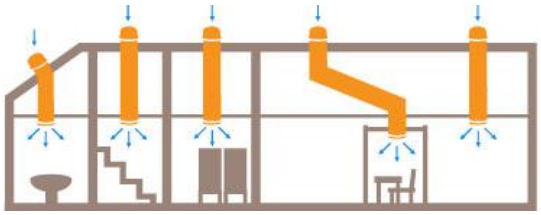
tiles. Use of Green Paint (low Volatile Organic Compounds) and anti-carbonation paints for internal and external walls. Use of LEED Certified materials.

Design for Innovations:

Sun pipes: Bringing the sunlight as the source of light into the building. Figures 15. (a), (b) and c).



a) Source: Light way Daylight – UK (Website)



b) Source: Light way Daylight – UK (Website)

c) Source: Ministry of Works - Bahrain

Figures 15, a, b and, c. Sun pipes (Showing natural light received in the building corridor, the outer part at the top of the roof, and other inner parts)

Design for Accessibility:

The design features for this school took into consideration the accessibility for physically disabled persons and pregnant women.

Other Design Considerations:

Parking and Arrival facilities. Approaches, entrances and hallways **(**i.e. Ramps, 3.6-meter-wide corridors and 1.5 meters wide hallways doors). Door and Doorways (i.e. Accessible by wheelchair and fixed with vision panels). Internal change of levels (i.e. elevators near the main entrances for vertical circulation with handicap accessibility). Sanitary requirements. And Safety (i.e. Security cameras in the corridors and external parking areas to ensure extra safety of students and women).

5.2.12 Lessons learned from Case study school project:

Preliminary Design Phase Lesson Learned: Main design considerations items are tabulated hereunder along with challenges, key issues and recommendations in Table 4.

Table 4. Preliminary Design Phase Lessons learned

Consideration Item	Challenge and Key Issues	Recommendations
Design Brief	Freezing design brief	To meet with Ministry of Education (MOE) and obtain approval on design requirements during design briefing process to minimize risks during detail design stage.
Budget	Budget confirmation. MOE requirements exceed initial budgets.	To resolve budget allocation before proceeding with design development phase. Design to cost and not cost to design.
Schedule Development	To meet planned schedule for design development activities.	The team needs to take into account lessons learned from experiences in dealing with various stakeholders prior to developing a schedule.
Communication	Problem in obtaining decisions from Client expeditiously.	Meet with the Client and minute decisions made.
Land Title	Some school projects proceed without land title.	A mechanism to be set up within the Ministry to assist relevant external agencies to expedite issuance of land title.
Land Survey	Availability of latest site demarcation points.	The Client to resolve the matter before proceeding with design development.
Technical and Authority Approvals	Compliance with the Authority's By-Laws.	Any ambiguities and issues to be officially addressed and resolved prior to proceeding with detail design.

Detail Design Phases Lessons Learned:

Main design considerations items are tabulated hereunder along with challenges, key issues, new design/materials and justifications/recommendations in Table 5.

Lesson Learned Conclusion:

- Create Lessons Learned **Culture**.
- **A culture** where we apply the best practices and discard the obsolete/bad ones

6. Discussion

The findings and results in this article concerning the integrated approach of greening of public-school buildings and environment elements showed that the nine outputs have a significant impact on: Saving energy and increase energy efficiency by employing renewable energy sources. Optimize water consumption. Use and reuse of eco-friendly materials. Improving air quality improves health and productivity. Improve the performance of school buildings, environment and the students. And Reduce emissions and other waste. The advantages of public green school

Table 5. Detail Design Phase Lessons learned

Consideration Item	Challenge and Key Issues	New Design/Materials	Justifications/ Recommendations
Green Building Practices	Most of the Green Materials are imported thus cost more to the overall building cost.	Traditional Decision Model = Cost + Function. While Green Decision Model = Cost + Function + Environment.	To address the benefits of Green Building Design and Solutions to the Client (Life Cycle Cost)
Space Planning		Compact Design. Centralized Air Conditioning: Allocate Air Handling Unit Rooms and Increased Floor to floor heights. Canteen to be part of Multipurpose Hall. Teachers' Rooms layout: to be centralized /one level / open plan concept, location to be away from Administration.	Contemporary design. Energy Efficient. Aesthetics. Future Design Recommendations: Waiting Areas at Guard Room: to be glazed, air-conditioned & TV. Playground to be reinstated for the primary school part.
External Works		Parking Bays – Glass Fiber filament for the roof. Playground Area: Thermoplastic vulcanized Rubber Flooring. Dustbins & Benches – High Pressure Laminate. Pavement recessed lights.	For better durability and aesthetics
Building Façade		Glass Curtain Wall. Tinted, double-glazed, reflective. Aluminum Shading Louvers.	Contemporary design. Energy Conservation. Aesthetics. Alternative to curtain in classroom - anti – vandalism.
Finishes		Floor – PVC Sheet except wet areas. Internal Wall – Anti Graffiti Paint. External Wall – Anti Carbonate Paint, Stone Texture Spray Coating. Ceiling – e.g. Classrooms.	Durability, Hygiene Easy maintenance, Acoustics, Anti-vandalism Environmental friendly. Advisory Note: For painting color Shades - follow exactly Client's Requirements.
Doors/Gates		All internal wooden doors to be Fire Rated (1/2 hour). Gates changed from timber to wrought iron.	Fire Safety. Ease of maintenance. Durability.
Partitioning		Insulated External Walls – sandwich type. Lightweight partition.	Better Insulation/ Energy Saving. New By-Law Requirement. Reduce dead load.
Wet Areas (Toilets, Drinking Areas)		Partition – New Partition System. Sanitary Fittings/Accessories (WC) – Higher Specifications. Sensor Flow Wash Taps. Wall Control Plate For WC Cistern. Wall Mirror At Drinking Area. Vanity Top & Basin Monolithic, Acrylic Resin. Concealed Piping Systems.	Cost benefits. Improved design solution. Durability and Anti-Vandalism. Water Conservation. Space enhancement/ aesthetics. Anti-Corrosion. Ease of maintenance.
School Operating Equipment		Electronic boards for all classroom	Functionality and Information Technology friendly
Building Services		Centralized A/C. Building Management System. Light Control Systems – Auto sensor. Security Cameras. Public Address System.	Energy Saving. Security.

buildings are far more than the disadvantages of possible higher cost, lack of expertise, and lack of training. The advantages have many benefits on the environmental, economic, financial, social, technological, and psychological levels. The investigation and review of related statistics, case studies and lessons learned within this article showed that these advantages have a great impact on school building performance, and students' and teachers' lifestyle and behaviors.

The Green school buildings and environment design guidelines output showed a significant impact in achieving better and adequate detailed design solutions, this impact was clear in Bahrain first green school case study. Performance measuring and rating tools for green school buildings are an important output due to its effective role in rating the environmental merits of an education facility through its life span in order to achieve and maintain a high performance. In the Arabian Gulf and the Arab Region there is still a need for more serious research to fill the gap in this area. This is one of the reasons to prepare this article and presenting the Bahrain Case Study. The lessons learned have a vital role, due to their importance in applying best practices as the project cannot be closed without the inclusion of the lessons learned file. The lessons learned document contain gathered knowledge throughout the project cycle on what worked and what didn't, contributing more effectively to the outcomes of future projects.

The various issues arising and how they were addressed are recorded and filed in the lessons learned document regularly and continuously by the project different team members giving them the opportunity to share their experiences in an open manner for future improvements and advance organizational learning. Moreover, they contribute to improving and updating the policies and procedures of the organization and sending them to the appropriate organizational unit. Lessons learned can help in measuring stakeholder satisfaction and feedback after the project completion.
There is significance evident of the green schoolyard as a space necessary for the students due to its positive effects on students' physical activities that were confirmed in many of the reviewed studies. The schoolyard was reflected in the Bahrain Case Study in the form of a controlled Multipurpose Hall that is centrally located to serve as the heart of the school and to allow for more generous and dynamic spaces for the students for their various activities.
Adopting the Descriptive Qualitative Method requires a vast multi component research data and literature review, that need to be screened and integrated in order to reach a final possible solution

of achieving a sustainable green school buildings and sourounding enviornment. **Figure 1: "Schematic Diagram Displaying Stages of the Research Process"** of this article summarizes what have been addressed and achieved of these multi components and bringing them together in one frame to facilitate visualizing and understaning the proposed approach and the outcomes.

In conclusion, the future of green school buildings looks bright and a step forward to to address climate challenges, with an increased focus on energy efficiency, optimized water and other natural resources consumption, modular construction, green building performance ratings systems, technology integration, and occupant health and well-being.

7. Conclusion

In conclusion greening school buildings and environment is a vital and an important possible solution to address factors affecting negatively our life due to many reasons that include climate and weather challenges, human aggressive behavior towards nature, and building design flaws and other related causes. Therefore, this study illustrated and emphasized that through the nine output results, green school buildings and environment can be achieved by combining, integrating and adopting a holistic elements approach to cope with hot and humid climate challenges. Thus, such a holistic elements approach and solution to address various issues can help support each of proposed hypotheses effectively. The stated three hypotheses of establishing a set of design guidelines, presenting case studies and lessons learned for knowledge dissemination, and applying criteria for enhancing the performance rating of schools, environment, and students were addressed by adopting the Descriptive Qualitative Method. This method involves a vast amount of literature, data and information to be collected, reviewed and sorted out in significant categories for greening school buildings and environment. Statistics and other reviewed classified selected literature concerning various applied greening aspects, guidelines, checklists, case studies, and performance-rating tools showed a strong significant support to, and agreement with the contents of the three hypotheses in terms of minimizing climate challenges negative impacts, save energy and water consumption, optimize utilization of natural resources, improve performance and productivity, and enhance life quality. Data and information included in Bahrain case study and lessons learned contributed to sharing experience and related knowledge with others to develop greening future and existing school buildings. Still there is a need to compare the Bahrain case study green school's actual performances in terms of water and energy consumption and expenditures, and students'

performance to other government traditional schools or even other green schools in Bahrain or elsewhere in the Arab World Region to explore the level of benefit consequences of each approach choice. Finally, this research article recommends greening public-school buildings and environment by adopting a holistic elements approach to cope with harsh, hot and humid climate challenges. Taking into consideration the nine output findings that include the followings: green school buildings characteristics, advantages, guidelines, performance and rating, significant statistics, innovation and technology to enhance our student's health and performance while preserving our natural resources and environment. Bringing all these fragmented elements into one integrated comprehensive design solution will enable the concerned authorities to foster a deep understanding of sustainability within students as a teaching pedagogical tool in addition to share this information with the whole community resulting in a better quality of life to students and future generations.

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