buildings

MDPI

Article

Indoor Environmental Quality for Comfort Learning Environments: Case Study of Palestinian School Buildings

Aya Baba [1,*], Isam Shahrour [1] and Mutasim Baba [2]

[1] Laboratory Civil Engineering and Geo-Environment Laboratory (LGCgE), Lille University, 59000 Lille, France; isam.shahrour@univ-lille.fr

[2] Faculty of Engineering and Information Technology, An-Najah National University, Nablus P400, Palestine; mutasimb@hotmail.com

* Correspondence: ayababa1993@gmail.com

Abstract: This research evaluates the quality of the indoor environment and comfort of Palestinian public schools. The importance of this study is related to the pivotal role of indoor environmental quality (IEQ) on students' health, well-being, and academic performance, especially in a region facing significant challenges such as limited financial resources and diverse climate conditions. Unlike traditional technical evaluations, this research uses a post-occupancy evaluation (POE) methodology. This research is based on a questionnaire about classes' indoor environment and comfort parameters, including thermal comfort, lighting, acoustics, indoor air quality, and ergonomic environment. The research focuses on students' overall well-being, considering factors often overlooked in traditional assessments. Key findings reveal significant challenges in thermal conditions due to inadequate heating, cooling, and ventilation systems and a lack of passive thermal design. High carbon dioxide levels in classrooms due to inadequate ventilation highlight a second critical challenge. Schools also suffered from noise pollution due to the absence of noise-absorbing materials. Students expressed their satisfaction with the lighting and indoor ergonomic comfort. This research resulted in recommendations to address classrooms' IEQ challenges, focusing on strategies to improve thermal comfort, acoustics, and indoor air quality.

Keywords: indoor environmental quality; post-occupancy evaluation; questionnaire; thermal comfort; acoustics; lighting; indoor air quality; ergonomic comfort; Palestinian; schools

Citation: Baba, A.; Shahrour, I.; Baba, M. Indoor Environmental Quality for Comfort Learning Environments: Case Study of Palestinian School Buildings. *Buildings* **2024**, *14*, 1296. https://doi.org/10.3390/buildings14051296

Academic Editor: Marilena De Simone

Received: 27 March 2024
Revised: 25 April 2024
Accepted: 30 April 2024
Published: 4 May 2024

1. Introduction

Achieving high indoor environmental quality (IEQ) is a significant concern because individuals spend approximately 90% of their lives indoors [1] . Ref. [2] highlighted the role of the indoor environment in shaping individuals' health, well-being, and overall quality of life. Furthermore, IEQ assessment is critical in the broader context of sustainability and building performance certification programs [3]. The total weight of IEQ in sustainability assessments ranges from 10% to 31% [4]. Recent global events, such as the COVID-19 pandemic, have underscored the urgent need to create indoor environments that prioritize occupants' health and well-being [5].

Educational buildings, including schools, play a pivotal role in society as many of the world's population spend more than 30% of their time in educational institutions [6]. Educational spaces' overall indoor environmental quality is shaped by several factors, mainly, indoor air quality, thermal comfort, acoustic comfort, visual comfort, ergonomics, and safety. Within educational settings, the effects of IEQ factors on students' health, well-being, and academic performance are significant [7]. Getting plenty of daylight improved students' performance by 7% to 18% [8]. Inadequate lighting can disrupt circadian rhythms, affecting hormone levels and the sleep–wake cycle. Children are more sensitive to temperatures than adults [9]. This sensitivity is attributed to their high metabolic rates and

limited opportunities for adaptation in classroom environments. Furthermore, research [10] showed that children are more vulnerable to air pollutants than adults due to immature lungs and metabolic factors. Poor IEQ in the classroom has been associated with decreased attention span and adverse effects on memory and concentration among pupils.

Traditional methods for assessing indoor environmental quality (IEQ) included technical approaches with sensors to collect indoor data [11]. These approaches often ignore the human experience. The question of how IEQ impacts people, particularly the young, remains open. This gap highlights the need for a more comprehensive approach that considers the feelings and experiences of occupants. Post-occupancy evaluation (POE) systematically evaluates occupied buildings' performances across various IEQ criteria [12]. The main strength of POE is its ability to identify specific needs within a building and guide improvements that enhance comfort for occupants [13]. As a POE tool, the questionnaire efficiently assesses IEQ [14].

Several scholars have used POE to examine indoor environmental quality (IEQ) in educational settings. Table 1 presents some of these studies and illustrates the highlighted results.

Table 1. Review of IEQ studies of educational institutions.

	Authors	Case Study	Region	Highlighted Results
1	[15]	Analyzed 26 higher education buildings (involving 1013 students and teachers).	Spain	The results highlighted the influence of building characteristics such as lighting, shade, and HVAC systems on occupants.
2	[16]	Analyzed three classes of a secondary school with 58 participants.	Haacht, Belgium	The results highlighted the influence of projector noise and whiteboard visibility on students' satisfaction.
3	[14]	Analyzed the feedback of 790 occupants of eight Roman schools.	Romania	The results highlighted a need to improve ventilation due to a lack of air quality and thermal comfort.
4	[11]	Applied to 796 undergraduate students at the University of Coruña.	Spain	Their study revealed the influence of the connection between place and classroom design on academic outcomes.
5	[17]	Surveyed 805 children in 32 well-ventilated classrooms.	United Kingdom	The results highlighted that to ensure a satisfactory comfort level and maintain the likelihood of discomfort below 10%, it is important to adhere to specific limits for ASV (air sensation vote) and Top (operative temperature) as follows: [ASV = very fresh and Top = 19–27 °C], [ASV = fresh and Top = 19–24 °C], and [ASV = OK and Top = 19–22 °C].
6	[18]	Evaluated classroom ventilation in both air-conditioned (AC) and naturally ventilated (NV) urban school buildings.	South Delhi, India	The results showed the importance of classroom ventilation and recommended specific measures to improve indoor air quality.
7	[19]	Quantitative and qualitative evaluation of four schools.	Jericho and Nablus, Palestine	The results highlighted the critical need for a new early-stage approach in school design that integrates environmental enhancements to optimize comfort for students and teachers.
8	[20]	Quantitative analysis of some thermal comfort parameters for one year in Wadi al Mughair School.	Hebron, Palestine	The results highlighted the positive effect of the ground channel and solar chimneys on hot and sunny days in classrooms.
9	[21]	Analyzed 30 classrooms in two urban secondary schools and three primary schools.	London, UK	The results highlighted several considerations, such as ventilation conditions, classroom size, floor type, and number of occupancies, to reduce exposure to fine particles within schools.

Table 1. *Cont.*

	Authors	Case Study	Region	Highlighted Results
10	[22]	Analyzed indoor air quality (IAQ) in 36 classrooms at six schools (involving 105 teachers and 1268 pupils).	Finland	The study found differences in both measurement and questionnaire data between classrooms. It also highlighted the need to expand the questionnaire to all occupants across all sections of a building for a comprehensive understanding of all spaces.
11	[23]	Evaluated teachers' psychological, social, and physical well-being in 32 schools.	Manitoba, Canada	The results found that ventilation and thermal comfort were the most important measures of teachers' physical well-being, while lighting, acoustics, and privacy were not significant measures of well-being.
12	[24]	Assessed IAQ factors in 220 classrooms.	Midwestern US	The results confirmed that mechanical system types, adequate ventilation rates, and effective filters have significant positive correlations with student learning outcomes.
13	[25]	Analyzed satisfaction in five schools including three high-performance schools, one recently renovated school, and one conventional school.	Major city on the East Coast ofthe United States	The results showed that the three high-performing school buildings did not perform better compared to the renovated and traditional school buildings. This suggests that current high-performance design standards may not adequately prioritize reducing health-related pollutants in urban school environments.
14	[26]	In total, 335 children from seven primary schools participated.	Delft, the Netherlands	The results showed that noise caused by students is the biggest problem in classrooms. Girls reported more problems than boys. Students can also be valuable contributors to the co-design of "new" or "adapted" classroom environments.
15	[27]	Analyzed IEQ in classrooms (involving 11 lecturers and 24 students).	---	The study findings indicated that both lecturers and students face substandard conditions related to thermal comfort, lighting, acoustic quality, and indoor air quality (IAQ), which may impact teaching and learning abilities.

The Palestinian education system suffers from poor infrastructure because of the occupation's financial and strategic restrictions [28]. According to [29], the practices of the Israeli occupation constitute barriers to providing regular health services to schools and deprive students of safe access to schools. Ref. [30] highlighted the impact of limited financial resources on the sustainability of public infrastructures and services. Schools suffer from this limitation. The absence of green construction standards for schools also hurts the learning conditions in schools [31]. Ref. [19] highlighted the importance of optimal thermal, lighting, and acoustic conditions in schools that are conducive to a good learning experience. This research contributes to improving IEQ in schools in Palestine by investigating the students' perception of the natural indoor environment in the classrooms and determining a strategy to improve IEQ in schools. This research is based on a post-occupancy evaluation (POE) survey conducted in three public schools of Tulkarm and Nablus governance in the West Bank, Palestine.

This paper is organized as follows: Section 2 defines the research methodology and materials and describes the protocol for collecting, selecting, and analyzing student data. Section 3 presents and discusses the research results. Finally, Section 4 summarizes the main issues and proposes recommendations to improve IEQ in public schools in Palestine.

2. Research Methodology and Materials

This study included three stages. The first one focused on selecting indoor environmental quality (IEQ) parameters. The second stage identified the study area and the school selection process. Finally, the third stage focused on developing the questionnaire and collecting data, which were analyzed to understand the students' feedback about IEQ in the classrooms.

2.1. Selection of IEO Parameters

In educational settings, the impact of IEQ is significant. Creating an environment that supports students' physical and mental health is essential for compelling learning experiences. Factors such as thermal comfort, lighting, acoustics, indoor air quality, and ergonomic considerations are pivotal in ensuring students are comfortable, healthy, and able to focus on their studies. Each of these parameters influences students' academic performance, concentration, and overall comfort within the school premises. The selection of these factors aims to comprehensively assess the overall quality of internal environments in Palestinian schools.

1. Thermal Comfort

Ensuring optimal thermal comfort within school environments is crucial because it profoundly impacts students' academic performance and overall health. Maintaining proper indoor temperatures and humidity rates dramatically impacts students' ability to learn effectively [32]. Extreme temperatures, both extreme cold and extreme heat, have been linked to decreased student cognitive functions and academic performance. Ref. [33] proved that students in classrooms with comfortable temperatures show increased attention spans, better memory retention, and improved academic achievements compared to those in an unfavorable learning environment. Additionally, Ref. [34] emphasized that comfortable thermal conditions reduce discomfort and distraction, resulting in fewer health-related issues such as fatigue, headaches, and irritability among students.

In international standards and building certifications, thermal comfort is a pivotal factor, as is LEED, ASHRAE, and ISO. They emphasize the importance of thermal comfort in creating healthy indoor environments while recognizing its direct link to the well-being and productivity of occupants. Schools aiming for sustainability certifications often give significant weight to thermal comfort within overall indoor environmental quality (IEQ) standards, recognizing its pivotal role in achieving a good learning environment. Therefore, prioritizing thermal comfort in educational facilities is not only in line with international standards but also ensures that students have an environment conducive to learning that enhances their health, concentration, and academic success.

2. Lightning Comfort

Lighting comfort within school buildings is crucial to students' academic performance, health, and well-being. Lighting is crucial in creating an ideal learning environment, affecting students' concentration, mood, and visual acuity. Ref. [35] conducted a study to determine whether indoor lighting affected children's academic abilities by administering a questionnaire to 92 children aged 10–12 years in Denmark. The researchers found that the students' learning speed, concentration, and math skills increased when the lighting level constantly changed from warm light 2900 K-450 lux to dynamic cool light 4900 K-750 lux. Based on a questionnaire of 738 students in Delhi Champ, ref. [36] showed that lighting had a significant effect on students' concentration and academic performance and that lighting from 250 to 500 lux was associated with increased student concentration, which resulted in higher grades and improved student academic performance. Furthermore, adequate exposure to natural light has been linked to improved alertness and reduced eye strain and headaches among students [37].

Prioritizing lighting comfort in schools complies with international standards and contributes significantly to students' educational experiences. Implementing measures such as using energy-efficient lighting systems, optimizing natural daylight, and reducing

glare can enhance the overall lighting quality in educational spaces. By creating a well-lit environment, educational institutions can promote better academic performance, support students' visual health, and foster an atmosphere that is conducive to learning.

3. Acoustic Comfort

Acoustic comfort in educational settings is essential for students' academic success and well-being. Students in noisy environments often have difficulties understanding speech, resulting in decreased comprehension and learning outcomes. For example, ref. [38] analyzed how noise affects students' cognitive functions, which is related to students' learning performance. Two hundred and sixty-eight students from three different primary schools in Ulsan, Korea, were included: 135 boys and 133 girls aged 10–12 years. The results showed that noise significantly affected global IQ scores, verbal IQ scores, Continuous Performance Test scores, Children's Color Paths Test scores, and Stroop test scores. These results suggest that noise risks the attention and performance of elementary school students, especially for groups most at risk of poor academic achievement.

Prioritizing acoustic comfort in schools complies with international standards (such as ANSI, WELL, and ISO) and contributes significantly to students' educational experiences. Implementing sound-absorbing panels, proper sound insulation, and noise reduction strategies can improve the overall acoustic quality in educational spaces. By addressing acoustic comfort, educational institutions can promote better learning environments, enhance student concentration and comprehension, and ultimately enhance academic success and overall well-being.

4. Indoor Air Quality

Optimal indoor air quality (IAQ) is the cornerstone of providing good learning environments within educational institutions. Its importance lies in the profound impact on students' academic performance and health. When indoor spaces suffer from poor air quality due to pollutants, insufficient ventilation, or contaminants, students may experience various health problems such as respiratory illnesses, allergies, headaches, and fatigue [39]. Furthermore, poor indoor air quality negatively affects students' ability to concentrate and retain information, ultimately affecting their academic achievements. Ref. [40] showed that reducing carbon dioxide concentration from 2100 ppm to 900 ppm in classrooms would improve school tasks by 12% in terms of the speed with which tasks are completed and by 2% in terms of errors made. In addition, this reduction would improve performance on tests used to assess progress in learning by 5% and increase daily attendance by 2.5%. In addition, ref. [41] confirmed that classroom indoor odor significantly impacts learning, reading task, and verbal memory performance.

Prioritizing indoor quality in educational settings includes implementing robust measures such as effective ventilation systems, appropriate filtration mechanisms, and continuous monitoring protocols. These steps aim to support students' health by reducing illness-related absenteeism and enhancing their focus and concentration, directly impacting academic performance.

5. Ergonomic Comfort

Comfort in educational settings, including appropriate furniture and color selection, is essential for students' overall health and academic performance. Carefully designed furniture promotes good posture, prevents physical discomfort, and supports students' physical health [42]. Studies consistently prove that comfortable furnishings improve concentration levels and create an environment conducive to effective learning [43]. Equally important is the role of colors in shaping students' psychological and emotional responses. Colors directly impact mood and cognitive function, affecting students' concentration and overall mental state [44]. For example, calming colors like blue and green are associated with reduced stress, while vibrant colors stimulate creativity and engagement [45]. In summary, the emphasis on ergonomic comfort through well-designed furniture and strategic color

choices plays a pivotal role in fostering an environment that supports students' physical health and positively impacts their concentration and academic achievement.

2.2. Research Material—School Selection

Occupants' feedback was gathered by a post-occupancy evaluation (POE) survey conducted in three public school buildings of Tulkarm and Nablus governance in the West Bank, Palestine. This selection was due to the possibility of obtaining information and data from the Directorate of Education and the municipalities and schools. These regions have a Mediterranean climate, which is characterized by dry summers and mild, wet winters, with winter temperatures ranging from 8 °C to 16 °C and summer temperatures ranging from 17 °C to 35 °C. The humidity level in this region remains relatively constant, ranging between 60% and 70%.

A lack of heating and ventilation systems is a general feature of schools in Palestine. Indeed, these systems are not required by the General Administration of School Buildings at the Ministry of Education. Public schools feature reinforced concrete structures, flat roofs, and masonry facades. Classrooms are equipped with single-glazed windows with high thermal transmittance (U-value = 5.7 $W/m^2.K$) and lack shading devices. Furthermore, no insulation is applied to the facades or the roofs of the surveyed buildings. Regarding occupancy density, some buildings exhibit a satisfactory student density, averaging 0.55 students per square meter (m^2).

Information was gathered from 331 students in 3 schools, including 200 students from Tulkarm (60%) and 131 students from Nablus (40%). The students' age range was 14 to 17, and 51% of participants were female.

2.3. Data Collection

The post-occupancy evaluation (POE) survey was used to evaluate indoor environmental quality (IEQ). POE surveys provide invaluable insights into occupant satisfaction with environmental conditions, serving as a vital measure of a building's ability to protect the health and comfort of its occupants [46]. Involving students in evaluating the quality of interior spaces provides baseline data and cultivates a collaborative approach to high indoor quality [47]. Their feedback can identify hidden problems, such as inadequate ventilation or uncomfortable seating, vital aspects of an IEQ test. They also foster a sense of ownership and empowerment among students, allowing them to actively participate in creating positive change [48]. At the policy level, insights gathered from POE surveys create a basis for evidence-based decision-making, guide school design improvements, and promote a healthier, more relevant learning environment for all [49].

The questionnaire design was based on the discussion presented in Section 2.1 about selecting IEQ parameters. The adaptation of these parameters to the Palestinian context was discussed with local experts in IEQ. The questionnaire was tested in some classes to check their clarity for students. Table 1 summarizes the 14 questions that were selected. They include the IEQ parameters discussed earlier: thermal comfort, acoustic quality, lighting, air quality, school furniture, and safety. In addition, they cover significant building areas, including classrooms, laboratories, and schoolyards. Thermal comfort was assessed for both winter and summer.

The questionnaire, administered in April 2023, sought students' retrospective assessments of their experiences during the preceding winter and summer seasons of the academic year 2022–2023. The questionnaire included 14 questions focusing on the significant aspects of IEQ, including thermal conditions, acoustic quality, lighting, air quality, school furniture, and safety. The questionnaire began with general details about the student, such as gender and age. Participants were then asked to rate their satisfaction with the IEQ. The survey used a scale to assess occupant satisfaction. These aspects were evaluated in academic building areas, including classrooms, laboratories, and schoolyards.

3. Results and Discussion

3.1. Students' Responses

Table 2 and Figure 1 show the distribution of descriptive numbers, percentages, and means of student perception of different types of IEO parameters that may contribute to the comfort level of classrooms.

Table 2. Student responses about IEQ in the classroom.

IEQ Parameters	Scale	Frequency	Percentage	Mean	Overall Mean
Thermal Comfort in Summer	Moderate	84	25	1.87	1.97
	Hot	121	37		
	Very Hot	126	38		
Thermal Comfort in Winter	Moderate	102	31	2.06	
	Cold	147	44		
	Very Cold	82	25		
Lighting Comfort in the Classroom	Bad	45	14	2.28	2.28
	Acceptable	147	44		
	Good	139	42		
Acoustic Comfort in the Classroom	Annoying	135	41	1.71	1.68
	Acceptable	156	47		
	Quiet	40	12		
Acoustic Comfort in Corridors and Yards	Annoying	147	44	1.64	
	Acceptable	156	47		
	Quiet	28	8		
Air Quality—Feeling Lethargic in the Classroom	No	104	31	2.18	2.26
	Sometimes	184	56		
	Always	43	13		
Bad Odors in the Classroom	No	103	31	2.13	
	Sometimes	167	50		
	Always	61	18		
Bad Odors in Laboratories	No	182	55	2.46	
	Sometimes	118	36		
	Always	31	9		
Safety and Security in School	No	49	15	2.46	2.46
	Sometimes	80	24		
	Always	202	61		
Color Ergonomic Comfort in School	Annoying and Ugly	57	17	2.13	1.99
	Acceptable	175	53		
	Beautiful and Pretty	99	30		
School Furniture Ergonomic Comfort	Annoying and Ugly	99	30	1.85	
	Acceptable	184	56		
	Comfortable	48	15		

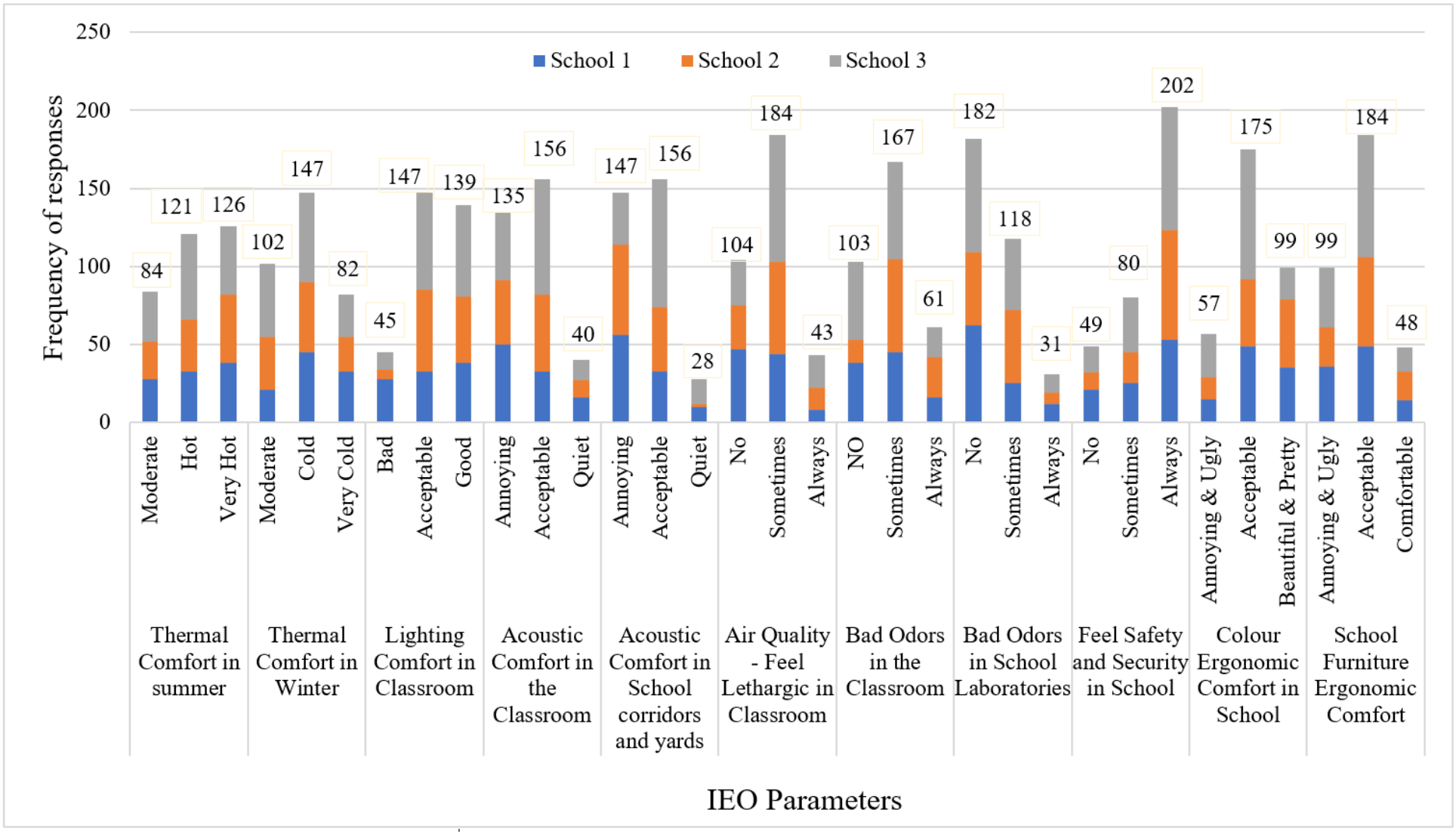

Figure 1. Student response evaluation of IEQ in the classrooms.

The overall mean values of each parameter of indoor environment quality (IEQ) were 1.97 for thermal comfort, 2.28 for lighting comfort, 1.68 for acoustic comfort, 2.26 for indoor air quality, 2.46 for safety, and 1.99 for ergonomic comfort. Safety and lighting comfort obtained the highest scores. Acoustic and thermal comfort obtained the lowest score. The results for each factor will be detailed in the following sections.

3.2. Thermal Comfort Analysis

Based on students' opinions in Figure 2 most (75%) of students found their classrooms uncomfortably hot and very hot in the summer. During winter, 69% of students expressed dissatisfaction with the classroom temperature, considering it cold or too cold. The reason for this is that these schools lack heating, cooling, and ventilation systems (HVAC). Therefore, students often resort to extra layers of clothing to deal with insufficient heating, as shown in Figure 2. In addition, 14% of schools have attempted to address this issue by installing electric heaters, as shown in Figure 3. However, this limited adoption highlights the ongoing challenge of consistently maintaining an appropriate temperature.

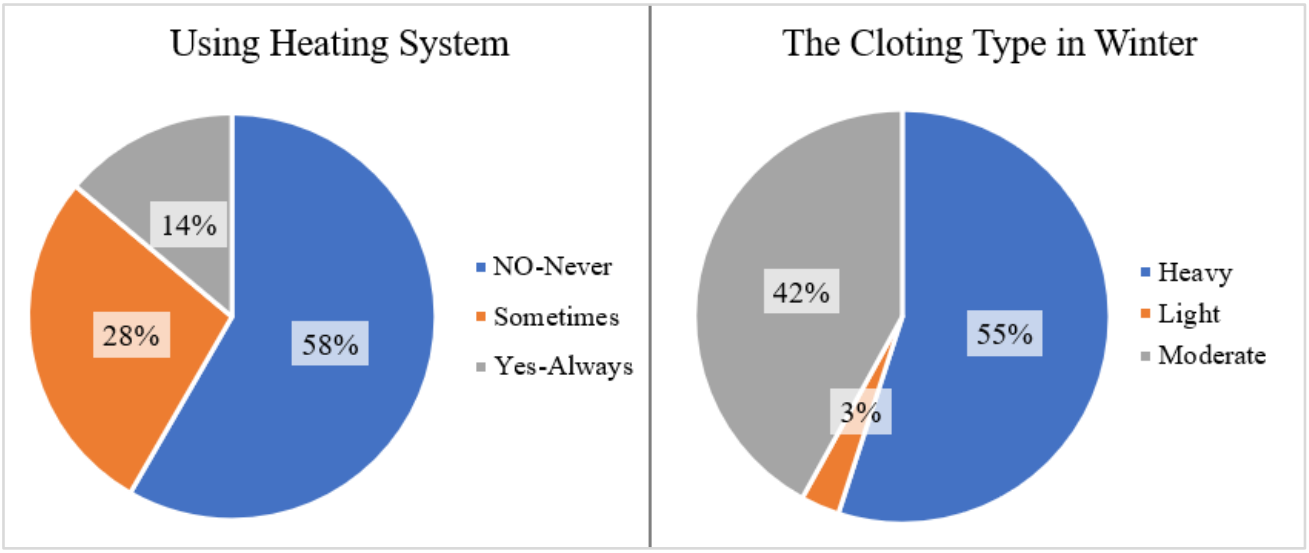

Figure 2. Thermal comfort in summer and winter in classrooms.

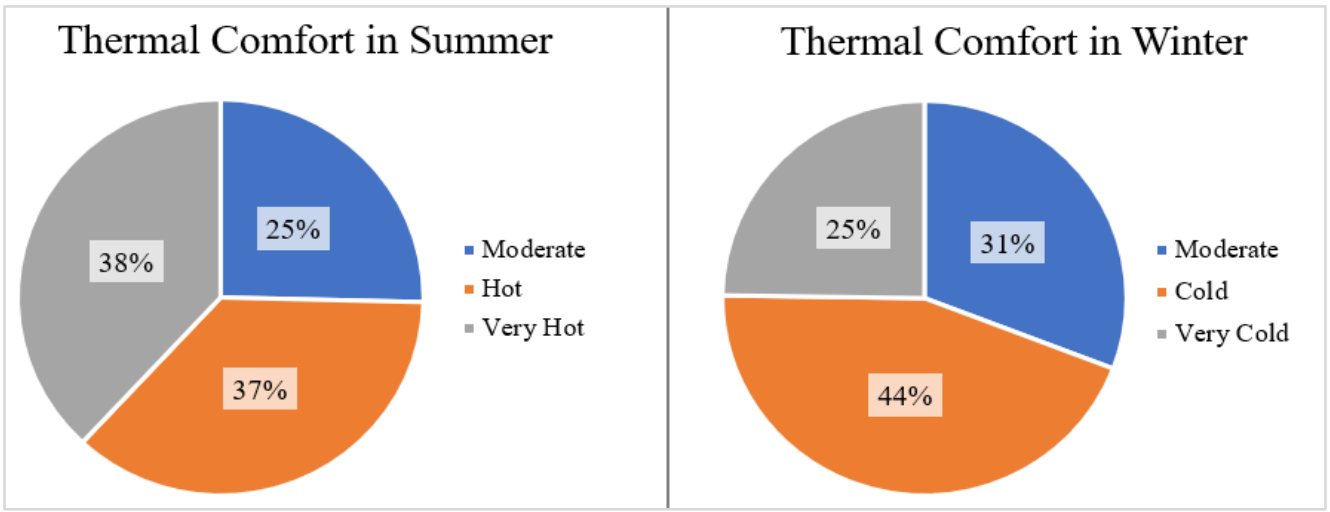

Figure 3. The proportion of heating system use and clothing type used in winter.

The observed results can be attributed primarily to financial constraints. The significant initial and ongoing costs associated with HVAC systems, including energy use and maintenance, create significant financial barriers to Palestinian public schools. As a result, these schools often need such systems, leaving students in unsuitable thermal conditions. Another contributing factor is that passive design principles should be considered. These principles effectively enhance indoor thermal comfort without relying solely on heating, ventilation, and air conditioning (HVAC) systems.

3.3. Lighting Comfort Analysis

Lighting comfort had a high mean level, which means that many students expressed satisfaction with the lighting levels in their classrooms. As shown in Figure 4, 86% of students found the lighting satisfactory, indicating a positive reception. Palestinian public schools rely heavily on T8 or T5 fluorescent tubes. However, there is an apparent effort to replace these lamps with LED lamps because of their advantages in terms of energy and lighting. However, this replacement only depends on replacing the defective bulbs and not replacing all the bulbs, which makes the process slow. Overall, based on students' opinions, it is clear that the lighting level in classrooms is sufficient.

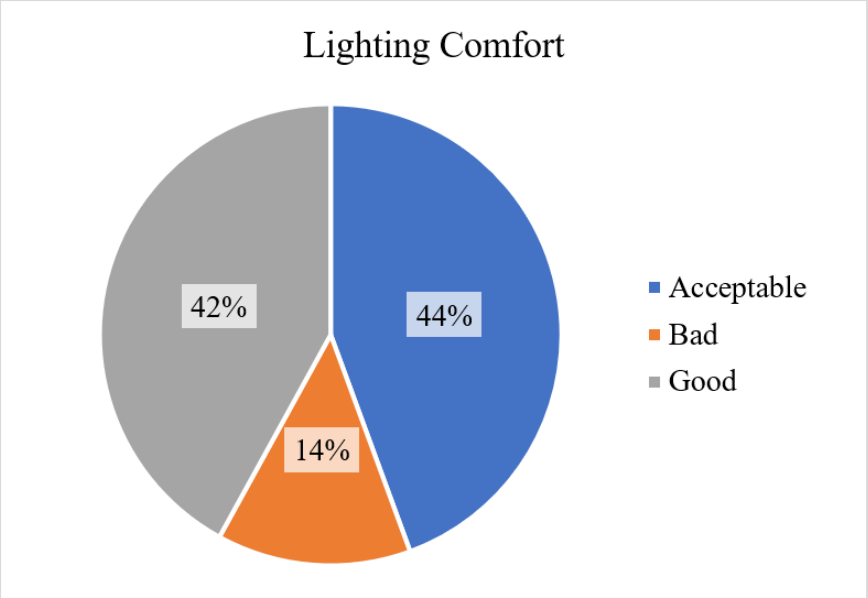

Figure 4. Lighting comfort levels in the classrooms.

3.4. Acoustic Comfort Analysis

As shown in Figure 5, nearly half of the students were satisfied with the acoustics in the classrooms and corridors. Noise pollution in classrooms comes from two sources: internal sources, such as communication or interaction between students, and external ones, like road traffic. Reducing internal sources depends on interior design, materials, and use of space. We found that these school buildings used traditional materials to furnish schools, which exacerbated indoor noise levels due to poor sound absorption properties. To address this problem, we propose using acoustic plaster in the ceilings of existing and newly constructed schools. In addition, we suggest designing the location of classrooms to be entirely away from sources of external noise, such as streets. This situation emphasizes the necessity of comprehensive acoustics to ensure a pleasant and harmonious auditory experience in educational spaces.

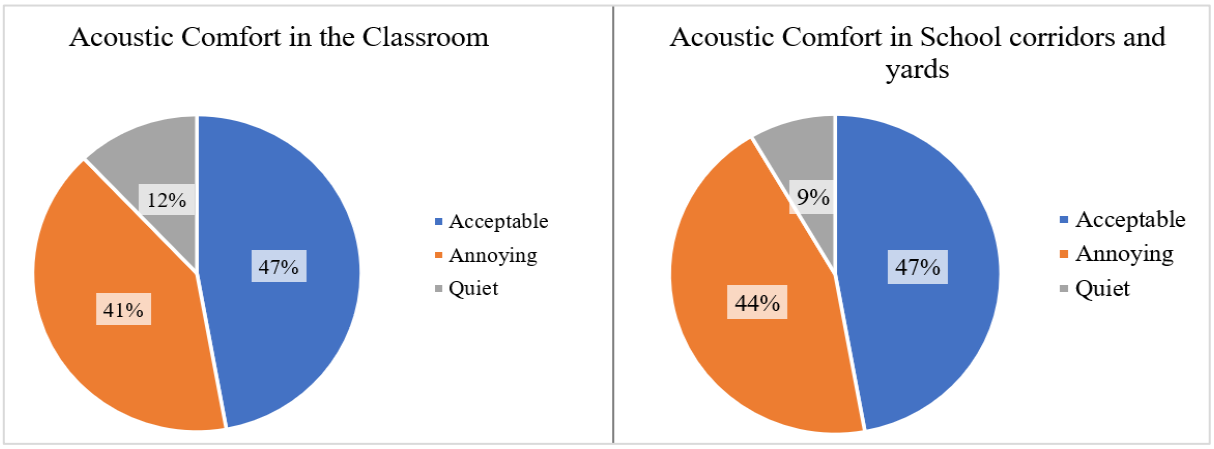

Figure 5. Acoustics comfort levels in the classrooms and school corridors and yards.

3.5. Indoor Air Quality Analysis

The presence of unpleasant odors was a notable concern in classrooms, with two-thirds of students reporting occasional to constant unpleasant smells, as illustrated in Figure 6. Additionally, 45% of students noticed similar odors in laboratories, emphasizing an urgent need to address odor issues comprehensively to foster a better learning environment. Moreover, a significant majority of students, over two-thirds, experienced lethargy in their classrooms, indicating elevated carbon dioxide levels due to inadequate ventilation. The deficient air quality in Palestine's public schools primarily results from the absence of ventilation systems in individual classrooms. The air quality in the laboratories is slightly better than in the classrooms, but this is due to the lower occupancy rate and slightly increased ventilation. However, in winter, the lack of heating systems means that classroom windows are closed, interrupting natural circulation and exacerbating air quality problems.

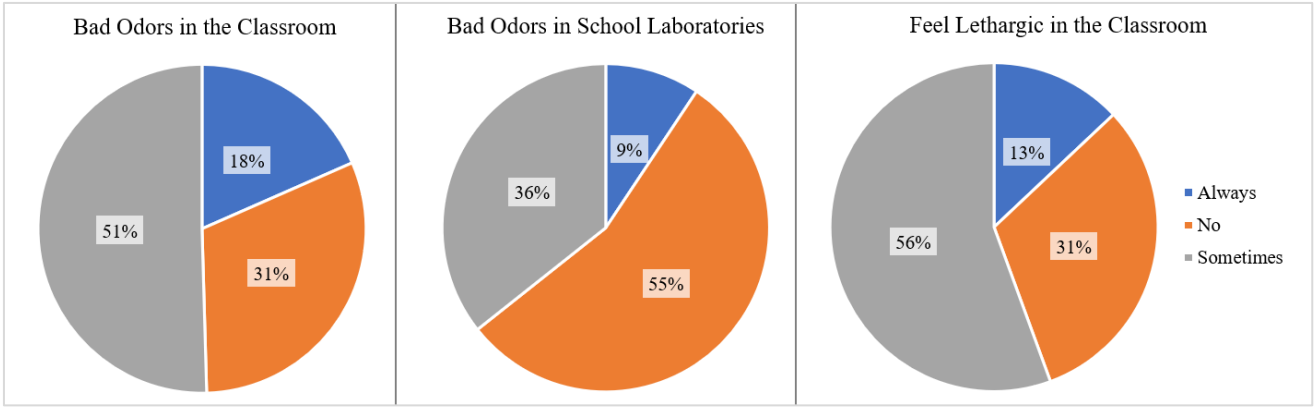

Figure 6. Air quality in the classrooms and laboratories.

3.6. Safety

Students' views on safety within the school environment varied, as shown in Figure 7. Most (over 60%) felt very safe due to clear security measures, including fences and gates surrounding most schools, creating a reassuring atmosphere. However, nearly a quarter of students expressed partial feelings of safety, which could be affected by various factors such as outdated infrastructure, inadequate security, inconsistent policies, or specific incidents involving unruly students. Significantly, perceptions of safety varied between schools, with some older institutions arousing discomfort.

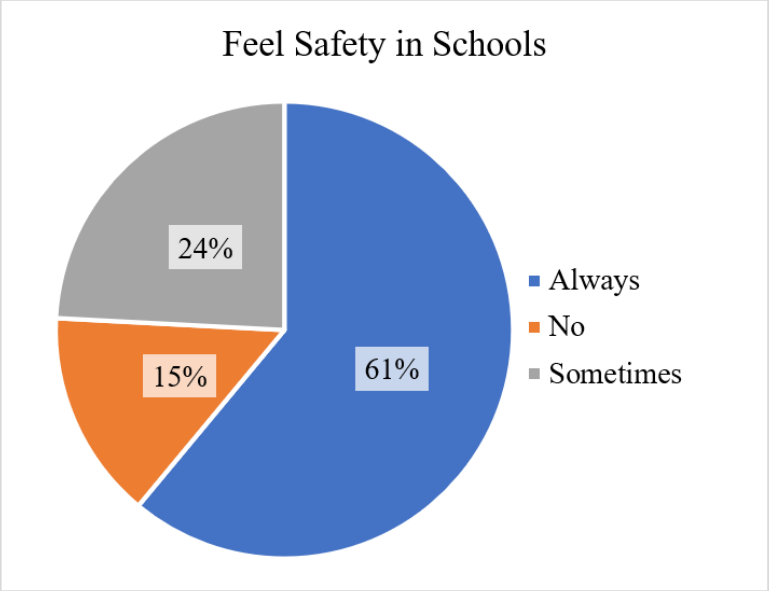

Figure 7. Feeling of safety in schools.

3.7. Ergonomic Comfort

Ergonomic comfort included two factors, namely, color comfort and furniture comfort.

i. Color Ergonomic Comfort

As shown in Figure 8, more than 80% of participants expressed satisfaction with the decorative visual elements. This positive feeling came from educational institutions' meticulous attention to detail, as evidenced by their commitment to the color standards set by the Ministry of Education. This regulation specifies color schemes for interior and classroom design, which have been carefully designed to suit the age groups of students. This thoughtful approach enhances the attractiveness of the environment and contributes significantly to the overall satisfaction of most students.

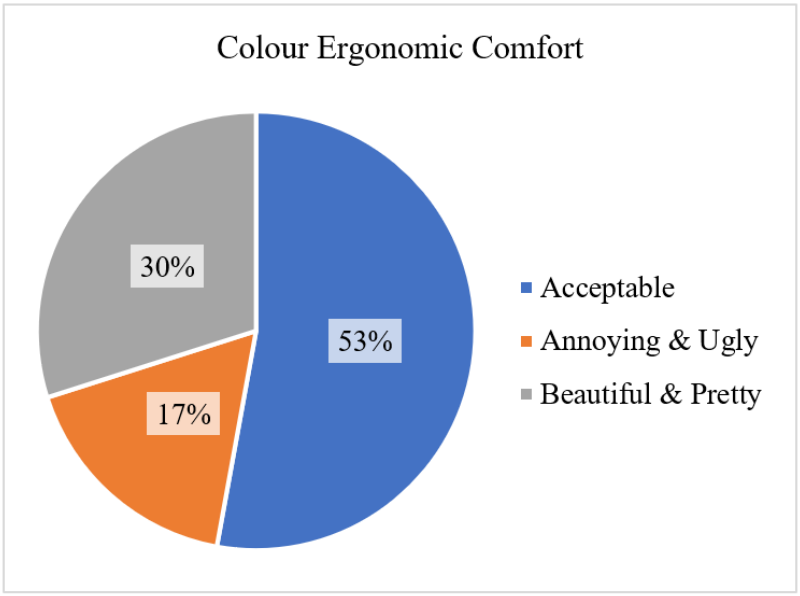

Figure 8. Color ergonomic comfort.

However, around 20% of students expressed dissatisfaction with the aesthetic aspects of their school buildings, finding them unattractive or distracting. This discontent stemmed

partly from the lack of innovative design and aesthetics of some school structures. In such cases, the lack of visually appealing elements may reduce satisfaction with existing colors and decorations. In addition, individual perceptions and preferences greatly influence students' satisfaction with colors, resulting in varying satisfaction levels among students.

ii. Furniture Ergonomic Comfort

Examining the classroom furniture revealed that students had different opinions, as shown in Figure 9. More than 70% of participating students expressed satisfaction with the ergonomic features of the classroom furniture, finding it attractive and well-suited to their needs. Conversely, nearly 30% of students expressed dissatisfaction, citing concerns regarding comfort and aesthetics. While some students found the chairs uncomfortable, others found them unattractive. An important factor contributing to these negative ratings was irregular maintenance in some educational institutions. When essential maintenance is overlooked, the quality and usability of the furniture deteriorate, affecting the overall beauty of the learning environment. Moreover, financial constraints often hinder furniture replacement, resulting in students experiencing prolonged discomfort due to the wear and tear of old furniture.

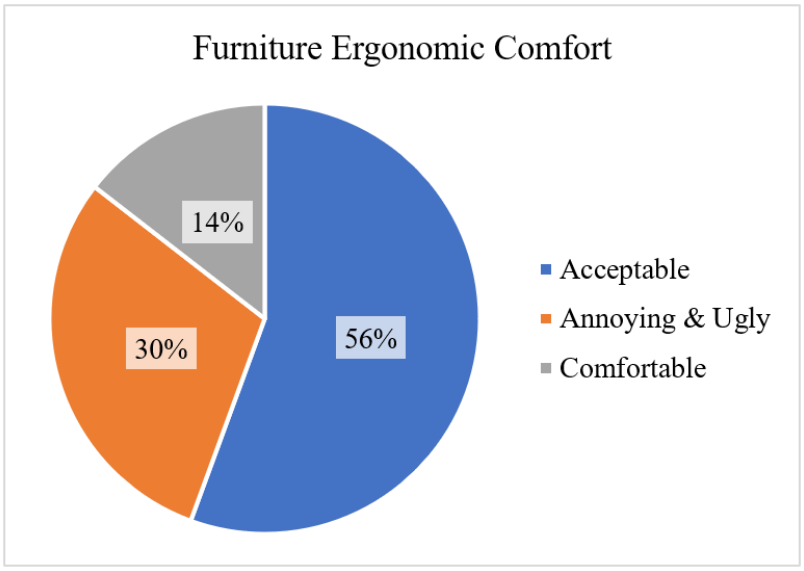

Figure 9. Furniture ergonomic comfort.

4. Discussion

The survey conducted on IEQ in Palestinian classrooms highlighted several critical issues that significantly impact students' learning and health. The primary concerns identified include inadequate thermal and acoustic comfort and poor air quality.

Thermal comfort emerged as the most critical factor due to substandard building insulation and outdated technical equipment. A lack of adequate insulation results in significant temperature variations, adversely affecting student concentration and health. While comprehensive building retrofit would be ideal, this would require substantial investment, which may not be immediately feasible. In the short term, thermal comfort can be improved by installing efficient ventilation systems and adding window shutters to mitigate heat loss and gain.

Acoustic discomfort in classrooms was another significant issue hindering effective learning. Mitigating this problem involves both behavioral and technical strategies. Sensitizing students about noise reduction practices can have an immediate effect. Technically, installing noise-absorbing materials and optimizing classroom layouts can reduce noise levels. Additionally, external noise can be curtailed by implementing traffic calming mea-

sures around school zones, such as reducing vehicle speeds and improving road surfaces to decrease traffic noise.

Poor air quality in classrooms was primarily due to inadequate ventilation and low-quality materials in furniture and building finishes. Improving ventilation systems is crucial to ensure a continuous supply of fresh air. Selecting non-toxic, low-emission materials for furniture and interior finishes can reduce indoor pollutants. Furthermore, enhancing school cleaning protocols by integrating green cleaning products and optimizing cleaning schedules can minimize the presence of airborne chemicals, thus improving the overall air quality.

Addressing the IEQ challenges of classrooms should consider the individual impact of each IEQ parameter and the interactions among these parameters. For example, noise can distract and increase stress levels, potentially making other environmental discomforts more noticeable, including poor lighting or air quality. Poor air quality can exacerbate discomfort from inappropriate temperatures. The use of ventilation systems to improve air quality could create noise and reduce the acoustic quality. It could also reduce thermal comfort in winter if the ventilation does not include heated air. Natural light can influence thermal comfort through solar heat gain. It reduces the need for artificial lighting, which can reduce heat output from lights, aiding in better thermal management.

5. Limitations and Future Directions

This research provides significant insights into indoor environmental quality (IEQ) in classrooms across Palestine and its influence on student well-being. However, we acknowledge the following limitations, which could be addressed in future research:

(i) Scope of Interviews

This study was based on a small sample of interviews, which may have limited the breadth of student assessments concerning IEQ.

(ii) Geographic Generalization

Our research focused on a specific geographic area within Palestine. While this provided detailed local insights, it restricts the capacity to generalize these findings across the entire region.

(iii) Outdoor Environmental Conditions

The exclusion of outdoor environmental conditions from this study is another limitation. Outdoor conditions, such as air quality and noise levels, can impact IEQ in classrooms and comfort levels perceived by students. Their inclusion could provide a more comprehensive understanding of the factors affecting IEQ.

(iv) Lack of a Mathematical Model:

Furthermore, this research did not develop a mathematical model to quantify the impact of various metrics on IEQ. Such a model could be instrumental for policymakers and educational administrators in making informed decisions.

To overcome these limitations, future research should consider the following enhancements: (i) expand the interview pool by increasing the number of participants and including diverse groups such as technical staff, teaching staff, and students from different educational levels, (ii) ensure wider geographic coverage by including large geographic locations, (iii) incorporate outdoor environmental conditions in IEQ assessments, and (iv) develop a mathematical model for the impact of IEQ metrics to aid decision-making.

6. Conclusions

This paper evaluated the quality of the indoor environment and comfort in Palestinian public schools. The significance of this study is in recognizing the pivotal role that IEQ plays in students' health, well-being, and academic performance, especially in a region facing unique challenges such as limited financial resources and diverse climate conditions. The research methodology focused on classrooms in school buildings using post-occupancy

evaluation (POE) methodology. This research used a questionnaire to measure students' views on different IEQ measures. This study prioritized factors that are often overlooked in traditional assessments, providing a comprehensive understanding of students' overall well-being. The survey covered thermal comfort, indoor air quality, lighting, acoustics, and ergonomic comfort and highlighted the multifaceted challenges that are deeply intertwined with IEQ.

This study presented the results of a survey assessing 331 students' satisfaction with the indoor environment in three Palestinian schools. Noteworthy mean values were obtained for each IEQ parameter, with the highest values obtained for lighting and ergonomic comfort, while the lowest values were obtained for acoustic and thermal conditions. The absence of heating, ventilation, and air conditioning (HVAC) systems in Palestinian public schools significantly impacts thermal conditions, requiring robust passive design strategies, effective insulation, shading techniques, and implemented HVAC systems. Acoustic challenges highlighted the need for sound-absorbing panels to reduce noise levels, while air quality concerns emphasized the importance of effective natural and mechanical ventilation systems. This study acknowledges the positive feedback regarding lighting and safety but emphasizes continued attention to aesthetics and ergonomic aspects through regular maintenance.

Despite valuable insights, this study has limitations, primarily the number of interviews with students. Future steps should include expanding the scope of the analysis to include diverse areas in the West Bank, considering different environmental and social conditions. In conclusion, this research establishes a critical relationship between IEQ and student well-being, providing a comprehensive framework for targeted interventions. Collaborative efforts between educational institutions, policymakers, and stakeholders are essential to implement the recommended strategies and ensure that Palestinian schools develop ideal learning environments that promote well-being and academic success.

Author Contributions: Conceptualization, A.B.; Methodology, A.B.; Software, A.B. and M.B.; Validation, A.B. and M.B.; Formal analysis, A.B. and M.B.; Resources, A.B. and M.B.; Data curation, A.B.; Writing—original draft, A.B.; Writing—review & editing, I.S.; Visualization, A.B.; Supervision, I.S.; Project administration, I.S.; Funding acquisition, I.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

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

References

1. Tang, H.; Liu, X.; Geng, Y.; Lin, B.; Ding, Y. Assessing the perception of overall indoor environmental quality: Model validation and interpretation. *Energy Build.* **2022**, *259*, 111870. [CrossRef]
2. Shamseldin, A.; Balabel, A.; Alwetaishi, M.; Abdelhafiz, A.; Issa, U.; Sharaky, I.; Al-Surf, M.; Al-Harthi, M. Adjustment of the indoor environmental quality assessment field for Taif city-Saudi Arabia. *Sustainability* **2020**, *12*, 275. [CrossRef]
3. Licina, D.; Wargocki, P.; Pyke, C.; Altomonte, S. The future of IEQ in green building certifications. *Build. Cities* **2021**, *2*, 907–927. [CrossRef]
4. Larsen, T.S.; Rohde, L.; Jønsson, K.T.; Rasmussen, B.; Jensen, R.L.; Knudsen, H.N.; Witterseh, T.; Bekö, G. IEQ-Compass – A tool for holistic evaluation of potential indoor environmental quality. *Build. Environ.* **2020**, *172*, 106707. [CrossRef]
5. Patial, S.; Nazim, M.; Khan, A.A.P.; Raizada, P.; Singh, P.; Hussain, C.M.; Asiri, A.M. Sustainable solutions for indoor pollution abatement during COVID phase: A critical study on current technologies & challenges. *J. Hazard. Mater. Adv.* **2022**, *7*, 100097. [CrossRef] [PubMed]
6. Kapoor, N.R.; Kumar, A.; Meena, C.S.; Kumar, A.; Alam, T.; Balam, N.B.; Ghosh, A. A Systematic Review on Indoor Environmental Quality in Naturally Ventilated School Classrooms: A Way Forward. *Adv. Civ. Eng.* **2021**, *2021*, 19. [CrossRef]
7. Carton, Q.; De Coninck, S.; Kolarik, J.; Breesch, H. Assessing the effect of a classroom IEQ on student satisfaction, engagement and performance. *E3S Web Conf.* **2023**, *396*, 01052. [CrossRef]
8. Vijapur, D.; Candido, C.; Göçer, Ö. A Ten-Year Review of Primary School Flexible Learning Environments: Interior Design and IEQ Performance. *Build. Rev.* **2021**, *11*, 183. [CrossRef]

9. Kim, J.; Dear, R. De Thermal comfort expectations and adaptive behavioural characteristics of primary and secondary school students. *Build. Environ.* **2018**, *127*, 13–22. [CrossRef]
10. Shree, V.; Marwaha, B.M.; Awasthi, P. Indoor Air Quality Investigation at Primary Classrooms in Hamirpur, Himachal Pradesh, India. *Hydro Nepal J. Water Energy Environ.* **2019**, *24*, 45–48. [CrossRef]
11. López-Chao, V.; López-Pena, V. Purpose adequacy as a basis for sustainable building design: A post-occupancy evaluation of higher education classrooms. *Sustainability* **2021**, *13*, 11181. [CrossRef]
12. Lolli, F.; Marinello, S.; Coruzzolo, A.M.; Butturi, M.A. Post-Occupancy Evaluation's (POE) Applications for Improving Indoor Environment Quality (IEQ). *Toxics* **2022**, *10*, 626. [CrossRef] [PubMed]
13. Hameen, E.C.; Ken-Opurum, B.; Son, Y.J. Protocol for post occupancy evaluation in schools to improve indoor environmental quality and energy efficiency. *Sustainability* **2020**, *12*, 3712. [CrossRef]
14. Catalina, T.; Ghita, S.A.; Popescu, L.L.; Popescu, R. Survey and Measurements of Indoor Environmental Quality in Urban/Rural Schools Located in Romania. *Int. J. Environ. Res. Public Health* **2022**, *19*, 10219. [CrossRef] [PubMed]
15. Bortolini, R.; Forcada, N. Association between building characteristics and indoor environmental quality through post-occupancy evaluation. *Energies* **2021**, *14*, 1659. [CrossRef]
16. Carton, Q.; Kolarik, J.; Breesch, H. Design of a Retrospective Survey for Occupant Satisfaction with IEQ in Classrooms. In Proceedings of the IAQ 2020: Indoor Environmental Quality, Athens, Greece, 13–15 September 2021; pp. 1–10. Available online: https://www.researchgate.net/publication/365234394 (accessed on 16 October 2023).
17. Korsavi, S.S.; Montazami, A.; Mumovic, D. The impact of indoor environment quality (IEQ) on school children's overall comfort in the UK; a regression approach. *Build. Environ.* **2020**, *185*, 107309. [CrossRef]
18. Singh, P.; Arora, R.; Goyal, R. Classroom ventilation and its impact on concentration and performance of students: Evidences from air-conditioned and naturally ventilated schools of Delhi. *Lect. Notes Civ. Eng.* **2020**, *60*, 125–137. [CrossRef] [PubMed]
19. Hussian, H.; Barlet, A.; Baba, M.; Semidor, C. Evaluation for Environmental Comfort Performance in the Palestinian Schools. In Proceedings of the 32nd International Conference on Passive and Low Energy Architecture—Cities, Buildings, People: Towards Regenerative Environments, Los Angeles, CA, USA, 11–13 July 2016; pp. 1254–1261. Available online: https://www.researchgate.net/publication/308762434 (accessed on 27 September 2023).
20. Monna, S.; Baba, M.; Juaidi, A.; Barlet, A.; Bruneau, D. Improving thermal environment for school buildings in Palestine, the role of passive design. *J. Phys. Conf. Ser.* **2019**, 1343. [CrossRef]
21. Hama, S.; Kumar, P.; Tiwari, A.; Wang, Y.; Linden, P.S. The underpinning factors affecting the classroom air quality, thermal comfort and ventilation in 30 classrooms of primary schools in London. *Environ. Res.* **2023**, *236*, 116863. [CrossRef]
22. Järvi, K.; Vornanen-Winqvist, C.; Mikkola, R.; Kurnitski, J.; Salonen, H. Online questionnaire as a tool to assess symptoms and perceived indoor air quality in a school environment. *Atmosphere* **2018**, *9*, 270. [CrossRef]
23. Abdul-Manan, S.; Mohamed, H.I. Occupants' indoor environmental quality satisfaction factors as measures of school teachers' well-being. *Build. Environ.* **2017**, *119*, 99–109. [CrossRef]
24. Kabirikopaei, A.; Lau, J.; Nord, J.; Bovaird, J. Identifying the K-12 classrooms' indoor air quality factors that affect student academic performance. *Sci. Total Environ.* **2021**, *786*, 147498. [CrossRef] [PubMed]
25. Oldham, E.; Kim, H. IEQ field investigation in high-performance, urban elementary schools. *Atmosphere* **2020**, *11*, 81. [CrossRef]
26. Bluyssen, P.M.; Kim, D.H.; Eijkelenboom, A.; Ortiz-Sanchez, M. Workshop with 335 primary school children in The Netherlands: What is needed to improve the IEQ in their classrooms? *Build. Environ.* **2020**, *168*, 106486. [CrossRef]
27. Brink, H.W.; Lechner, S.C.M.; Loomans, M.G.L.C.; Mobach, M.P.; Kort, H.S. Understanding how indoor environmental classroom conditions influence academic performance in higher education. *Facilities* **2024**, *42*, 185–200. [CrossRef]
28. MacKenzie, A.; Bower, C.; Owaineh, M. Barriers to Effective, Equitable and Quality Education. *Int. J. Child. Rights* **2020**, *28*, 805–832. [CrossRef]
29. Ministry of Education, P. Education sector strategic plan 2017-2022; 2017; (Issue An Elaboration of The Education Development Strategic Plan III (2014–2019)). 2017. Available online: https://planipolis.iiep.unesco.org/sites/default/files/ressources/palestine_education_sector_strategic_plan_2017-2022.pdf (accessed on 3 June 2023).
30. Abu Hamed, T.; Peric, K. The role of renewable energy resources in alleviating energy poverty in Palestine. *Renew. Energy Focus* **2020**, *35*, 97–107. [CrossRef]
31. Mouzaneh, M.; Harun, Z.; Jamil, N. Awareness of Green Building in West Bank Palestine. *Int. J. Glob. Optim. Its Appl.* **2022**, *1*, 249–257. [CrossRef]
32. Liu, C.; Zhang, Y.; Sun, L.; Gao, W.; Jing, X.; Ye, W. Influence of indoor air temperature and relative humidity on learning performance of undergraduates. *Case Stud. Therm. Eng.* **2021**, *28*, 101458. [CrossRef]
33. Baafi, R.K.A. School Physical Environment and Student Academic Performance. *Adv. Phys. Educ.* **2020**, *10*, 121–137. [CrossRef]
34. van den Bogerd, N.; Dijkstra, S.C.; Tanja-Dijkstra, K.; de Boer, M.R.; Seidell, J.C.; Koole, S.L.; Maas, J. Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality. *Build. Environ.* **2020**, *171*, 106675. [CrossRef]
35. Hviid, C.A.; Pedersen, C.; Dabelsteen, K.H. A field study of the individual and combined effect of ventilation rate and lighting conditions on pupils' performance. *Build. Environ.* **2020**, *171*, 106608. [CrossRef]
36. Singh, P.; Arora, R.; Goyal, R. *Impact of Lighting on Performance of Students in Delhi Schools*; Springer: Singapore, 2020; Volume 60. [CrossRef]

37. Ticleanu, C. Impacts of home lighting on human health. *Light. Res. Technol.* **2021**, *53*, 453–475. [CrossRef]
38. Bhang, S.; Yoon, J.; Sung, J.; Yoo, C.; Sim, C.; Lee, C.; Lee, J. Comparing Attention and Cognitive Function in School Children across Noise Conditions: A Quasi-Experimental Study. *Psychiatry Investig.* **2018**, *15*, 620–627. [CrossRef] [PubMed]
39. Sadrizadeh, S.; Yao, R.; Yuan, F.; Awbi, H.; Bahnfleth, W.; Bi, Y.; Cao, G.; Croitoru, C.; Dear, R.; Haghighat, F.; et al. Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment. *J. Build. Eng.* **2022**, *57*, 104908. [CrossRef]
40. Wargocki, P.; Porras-Salazar, J.A.; Contreras-Espinoza, S.; Bahnfleth, W. The relationships between classroom air quality and children's performance in school. *Build. Environ.* **2020**, *173*, 106749. [CrossRef]
41. Choi, N.; Yamanaka, T.; Takemura, A.; Kobayashi, T.; Eto, A.; Hirano, M. Impact of indoor aroma on students' mood and learning performance. *Build. Environ.* **2022**, *223*, 109490. [CrossRef]
42. Alibegović, A.; Macak, A.; Pašalić, A.; Domljan, D. School FurnitureErgonomics in Preventionof Pupils' Poor Sitting Posture. *Drv. Ind.* **2020**, *71*, 88–99. [CrossRef]
43. Starkey, L.; Leggett, V.; Anslow, C.; Ackley, A. The Use of Furniture in a Student-Centred Primary School Learning Environment. *New Zeal. J. Educ. Stud.* **2021**, *56*, 61–79. [CrossRef]
44. Pourbagher, S.; Azemati, H.R.; Saleh Sedgh Pour, B. Classroom wall color: A multiple variance analysis on social stress and concentration in learning environments. *Int. J. Educ. Manag.* **2021**, *35*, 189–200. [CrossRef]
45. Amarin, N.; Al-Saleh, A. The effect of color use in designing instructional aids on learners' academic performance. *J. E-Learning Knowl. Soc.* **2020**, *16*, 42–50. [CrossRef] [PubMed]
46. Ampadu-Asiamah, A.D.; Amos-Abanyie, S.; Botchway, E.A.; Duah, D.Y.A.; Gyimah, K.B. Adoption of Indoor Environmental Quality Assessment Framework for Naturally Ventilated Classrooms in Basic Schools in Ghana. In *Sustainable Education and Development – Making Cities and Human Settlements Inclusive, Safe, Resilient, and Sustainable*; Springer: Singapore, 2022; pp. 109–123. [CrossRef]
47. Pittana, I. Assessing Overall Indoor Environmental Comfort and Satisfaction: Evaluation of a Questionnaire Proposal by Means of Statistical Analysis of Responses. In Proceedings of the IAQ 2020: Indoor Environmental Quality Performance Approaches, Athens, Greece, 4–6 May 2022; 2022; pp. 1–7.
48. Leccese, F.; Rocca, M.; Salvadori, G.; Belloni, E.; Buratti, C. Towards a holistic approach to indoor environmental quality assessment: Weighting schemes to combine effects of multiple environmental factors. *Energy Build.* **2021**, *245*, 111056. [CrossRef]
49. Li, P.; Froese, T.M. Gail Brager Post-occupancy evaluation: State-of-the-art analysis and state-of-the-practice review. *Build. Environ.* **2018**, *133*, 187–202. [CrossRef]