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QUESTIONNAIRE-BASED RESEARCH ON EDUCATIONAL BUILDING COMFORT

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Abstract— **This study conducted a comprehensive POE of IEQ in academic building at Rajkiya Engineering College Kannauj, Uttar Pradesh, India. The aim was to identify variations in IEQ perceptions across different floors and gather insights for improvements. A questionnaire assessed occupants' satisfaction with educational building comfort across all four floors over one week. 253 valid responses were collected through stratified random sampling. Descriptive statistics revealed disparities in factors like temperature, humidity, air movement, and air quality satisfaction scores. Inferential analysis confirmed statistically significant differences in overall IEQ satisfaction across floors. The 3rd floor showed a wide range of thermal comfort ratings, suggesting issues with temperature control, ventilation, or insulation. Around 30% reported odor issues across floors, indicating potential indoor air pollutants. Noise disturbances from external sources and lack of privacy were major acoustic challenges, particularly on the 3rd floor. Lighting quality received mixed feedback, with glare and discomfort frequently cited on the 3rd floor. Qualitative analysis provided additional insights into specific IEQ problems and areas for improvement. The findings highlight the importance of localized assessments and targeted strategies to address IEQ challenges in educational facilities, enhancing occupant well-being and academic performance.**

Keywords— **Post Occupancy Evaluation (POE), Indoor Environmental Quality (IEQ), Academic Building, Occupants' satisfaction.**

I. INTRODUCTION

Indoor Environmental Quality (IEQ) is a multifaceted concept encompassing various factors such as air quality, thermal comfort, lighting, acoustics, and spatial layout, all of which significantly impact the health, comfort, and productivity of building occupants [1] [2]. In educational settings, where students, faculty, and staff spend a considerable amount of time, ensuring high IEQ is essential for creating conducive learning and workingenvironments.

The indoor environmental quality (IEQ) of buildings, particularly in educational settings, has garnered significant attention due to its profound impact on occupants' health, well-being, and productivity [3]. Educational facilities serve as vital learning environments for students, making it essential to maintain optimal indoor conditions that foster academic performance and overall comfort [4]. IEQ encompasses various factors, including thermal comfort, indoor air quality, lighting, and acoustics, all of which can influence occupants' perceptions andexperiences within the built environment.

Thermal comfort, defined as the condition of mind that expresses satisfaction with the thermal environment [5], plays a crucial role in educational buildings. Deviations from acceptable temperature and humidity levels can lead to discomfort, decreased concentration, and impaired learning [6]. Similarly, poor indoor air quality, caused by factors such as inadequate ventilation, off-gassing from building materials, or outdoor pollutants, can contribute to health issues like respiratory problems, headaches, and fatigue [7].

Lighting quality, encompassing aspects like illuminance levels, glare, and color rendering, is another critical factor affecting visual comfort and task performance [8]. Improper lighting conditions can strain occupants' eyes, cause headaches, and negatively impact concentration . Acoustics, which involve sound levels, reverberation times, and noise control, are essential for effective communication and minimizing distractions in educational environments.

Poor IEQ has been associated with adverse health effects, discomfort, decreased cognitive function, and increased absenteeism among occupants [9]. For instance, exposure to indoor pollutants such as volatile organic compounds (VOCs), carbon dioxide (CO_2), and particulate matter can lead to respiratory problems, allergies, and reduced cognitive performance among students and teachers [9]. Similarly, inadequate thermal comfort, characterized by temperature fluctuations or overly warm or cold conditions, can impair concentration, learning,and productivity [10].

Despite its importance, many educational buildings face challenges in maintaining satisfactory indoor environmental conditions. Factors such as building design, ventilation systems, maintenance practices, and occupant behavior can all influence IEQ levels [11]. For example, building designs that prioritize energy efficiency may inadvertently compromise IEQ by limiting natural ventilation or exposure to daylight [12]. Similarly, improper maintenance of HVAC systems,

including inadequate filter replacement or ventilation rates, can lead to poor air quality and thermal comfort [13].

Conducting a thorough assessment of IEQ is crucial for identifying areas of improvement and implementing targeted interventions to enhance indoor environmental conditions [14]. Post-occupancy evaluations (POEs) provide valuable insights into occupants' satisfaction levels and the effectiveness of building design and management practices in meeting IEQ standards. Recognizing the multifaceted nature of IEQ and its impact on occupants' well-being, researchers have increasingly employed occupant satisfaction surveys as a valuable tool for evaluating indoor conditions [12]. These surveys gather subjective feedback from building occupants, providing insights into their perceptions and experiences with various IEQ factors. By understanding occupants' satisfaction levels, building managers and facility operators can identify areas of concern and implement targeted strategies to enhance indoor environmental quality.

While numerous studies have explored IEQ assessments in educational buildings [4], there is a need for more localized investigations that consider potential variations within a single building. This study aims to conduct a floor-wise occupant satisfaction survey in an educational facility to identify potential discrepancies in IEQ perceptions across different floors. By employing this approach, specific areas requiring attention can be pinpointed, enabling the development of tailored solutions to optimize indoor environmental conditions and promote a conducive learning environment.

II. METHODOLOGY

The study was conducted in a four-story educational building on the campus of Rajkiya Engineering College Kannauj, located in Kannauj, Uttar Pradesh, India. This facility houses various classrooms, laboratories, and faculty offices, with a total occupancy capacity of approximately 950 individuals, including students, instructors, and administrative staff. The building's construction dates back to 2015.

To assess the indoor environmental quality (IEQ) of this educational building, a comprehensive occupant satisfaction questionnaire was developed. The questionnaire design process involved a thorough review of existing literature on IEQ assessments, as well as consultation with subject matter experts in the fields of building science, environmental engineering, and occupational health.

The questionnaire encompassed four main sections: thermal comfort, indoor air quality, lighting, and acoustics. Each section included a series of questions employing a 7-point Likert scale, ranging from "extremely dissatisfied" to "extremely satisfied." Additionally, open-ended questions were incorporated to allow respondents to provide detailed feedback and elaborate on any specific concerns or issues.

The survey distribution process was conducted electronically, with personalized email invitations sent to all building occupants, including students, faculty members, and administrative personnel. The email included a brief introduction to the study, its objectives, and a unique link to access the online questionnaire. Participation was voluntary, and responses were collected anonymously to ensure confidentiality.

The data collection period spanned one week, during which periodic reminders were sent to encourage participation and improve the response rate. Upon completion of the data collection phase, the responses were compiled, cleaned, and prepared for analysis.

III. DATA ANALYSIS

A. Frequency Distribution

Table 1: Frequency Distribution

Satisfaction Score	1	2	3	4	5	6	7
Temperature	13%	12%	20%	23%	20%	8%	3%
Humidity	8%	14%	19%	28%	21%	7%	4%
Air Movement	5%	7%	14%	29%	25%	15%	5%
Thermal Comfort	10%	16%	21%	26%	17%	8%	2%
Fresh Air	7%	12%	16%	20%	27%	14%	5%
Odour	8%	10%	17%	26%	19%	17%	3%
IAQ	4%	8%	18%	26%	25%	14%	4%
Outside Noise	14%	18%	17%	23%	14%	8%	6%
Sound Privacy	9%	10%	17%	25%	23%	10%	7%
Acoustic Comfort	9%	12%	20%	21%	20%	12%	5%
Natural light	4%	7%	12%	18%	26%	22%	12%
Glare	5%	11%	18%	27%	19%	15%	5%

Lighting Comfort	6%	7%	19%	22%	25%	14%	6%
Overall IEQ	6%	8%	20%	22%	26%	14%	4%

This frequency distribution [Table 1] illustrates the distribution of occupant satisfaction scores for every question across all floors. It horizontally represents the frequency or percentage of respondents based on their sensation and it vertically displays the different parameters.

B. Descriptive Statistics

Table 2: Overall Satisfaction Score for Each IEQ Factor

LATENT VARIABLE	QUESTION	MEAN	MODE	MEDIAN	STAN-DARD DEVI-ATION
THERMAL COMFORT SATISFACTION	Please rate your satisfaction with temperature conditions of your classroom.	3.67	4.00	4.00	1.62
	Please rate your satisfaction with the overall humidity in your classroom	3.78	4.00	4.00	1.50
	Please rate your satisfaction with the airmovement available to you in your classroom.	4.28	4.00	4.00	1.46
	Please rate your satisfaction with the overall thermal comfort in your classroom.	3.62	4.00	4.00	1.51
INDOOR AIR QUALITY	Please rate your satisfaction with fresh air in your classroom.	4.12	4.00	5.00	1.61
	Odours in the classroom.	3.55	4.00	4.00	1.73
	Please rate your satisfaction with the overall air quality in your classroom.	4.21	4.00	4.00	1.46
ACOUSTIC COMFORT	Your classroom enables you to work without unwanted noise interruptions from outside of the academic block.	3.55	4.00	4.00	1.73

	Space ensures your conversations stay private. No one is listening.	4.02	4.00	4.00	1.62
	Please rate your satisfaction with the overall noise in your classroom.	3.92	4.00	4.00	1..63
LIGHTING CONFORT	Please rate your satisfaction with the lighting level in classroom.	4.69	5.00	5.00	1.59
	Do the lighting fixtures cause direct or indirect glare at your view point? Please rate your experience	4.12	4.00	4.00	1.53
	Please rate your satisfaction with the lighting comfort of your classroom (e.g. amount of light, glare, reflections, contrast).	4.25	4.00	5.00	1.54
OVERAL SATISFACTION	How satisfied are you with the overallindoor environ-ment of the educational building? please rate your experience.	4.14	4.00	5.00	1.48

The [Table 2] presents the descriptive statistics, including mean, mode, median, and standard deviation, for occupant satisfaction scores across various IEQ parameters on different floors. The mean scores provide an overall indication of the average satisfaction level, while the standard deviations highlight the variability in occupant responses. Higher standard deviations suggest greater divergence in perceptions and experiences among occupants.

C. Inferential Analysis

Table 3: Correlation Analysis

Variable	Thermal Comfort	Indoor Air Quality	Acoustic Comfort	Lighting Comfort
Thermal Comfort	1.00			
Indoor Air Quality	0.62	1.00		
Acoustic Comfort	0.52	0.57	1.00	
Lighting Comfort	0.41	0.50	0.55	1.00

This [Table 3] presents the results of a correlation analysis conducted to investigate the strength and direction of the relationships between various IEQ parameters. The table typically includes the Pearson correlation coefficients (r) for each pair of variables analysed. Correlation **coefficients** range from -1 to 1.

Table 4. ANOVA: Single Factor

Floor	Mean	Count	Standard Deviation	Standard Error
Ground	4.555556	63	1.20185	0.151419
1st Floor	3.955556	45	1.566054	0.233454
2nd Floor	3.847059	85	1.435153	0.155664
3rd Floor	4.266667	60	1.665876	0.215064

This [Table 4] presents the results of analysis of variance conducted to determine statistically significant differences exist in overall IEQ satisfaction scores across different floors of the educational building.

Table 5: ANOVA

Source of Variation	SS	df	MS	F	p-Value
Between Groups	20.66571	3	6.888569	3.210812	0.023656
Within Groups	534.2118	249	2.145429		

The ANOVA [Table 5] typically includes the source of variation (e.g., between floors), degrees of freedom (df), sum of squares (SS), mean squares (MS), F-statistic, and the corresponding p-value. A significant p-value $p < 0.05$ indicates that the mean satisfaction scores for the IEQ parameter differ significantly across at least two floors.

IV. RESULTS

This study aimed to evaluate the indoor environmental quality (IEQ) of an educational facility by conducting an occupant satisfaction survey across multiple floor. The survey covered various IEQ parameters. The analysis of collected data was revealed the significant findings and provided insights into areas that require attention and improvement.

Descriptive statistics showed a mean satisfaction score of 3.67 (on a 7-point scale) for temperature conditions across all floors, with a relatively high standard deviation of 1.62, indicating substantial variations in occupant responses. A similar trend was observed for humidity (mean = 3.8, SD = 1.6) and air movement (mean = 4.3, SD = 1.5). The survey responses indicated varying levels of satisfaction with thermal comfort conditions across different floors of the educational building. The 3rd floor showed a wider range of ratings, with some occupants reporting high satisfaction (scores of 6-7) while others expressed dissatisfaction (scores of 1-2) with factors like temperature, humidity, and air movement. The 1st and 2nd floors generally had more consistent ratings in the neutral to satisfactory range (scores of 3-5) for thermal comfort parameters.

Air quality satisfaction had a mean score of 4.2 with a standard deviation of 1.5, indicating a wide range of perceptions. The presence of odours was reported by approximately 30% of respondents across multiple floors. Air quality perceptions varied considerably among occupants. While some floors, like the 3rd floor, had a mix of high and low satisfaction scores for fresh air availability and overall air quality, the 1st floor showed more consistently positive ratings in this area. Odour issues were reported across multiple floors, suggesting potential areas for investigation or improvement.

For acoustics, the mean satisfaction score for the ability to have private conversations was 4.1 (SD = 1.7), while noise from outside had a lower mean of 3.6 (SD = 1.8), highlighting potential noise issues. These lower ratings, particularly on the 3rd floor, highlight the presence of acoustic issues that can adversely impact occupants' ability to concentrate and engage in learning activities effectively. Noise levels from outside the building and the ability to have private conversations were identified as concerns across several floors, particularly the 3rd floor where many occupants reported dissatisfaction. The 1st and 2nd floors had a more balanced distribution of ratings for acoustic comfort, indicating better noise control in some areas.

Lighting quality received a mean satisfaction score of 4.8 (SD = 1.6), with glare being a frequently citedconcern, particularly on the 3rd floor. A one-way ANOVA revealed statistically significant differences in lighting satisfaction across floors ($F(4, 195) = 3.27$, $p < 0.05$), with the 2nd floor having a lower mean score of 3.6 (SD =1.6) compared to the 1st floor (mean = 4.2, SD = 1.4). Lighting quality received mixed reviews, with occupants on 3rd floor frequently citing issues with glare, insufficient lighting levels, or overall discomfort. However, other floors, like the 1st floor, tended to have more positive ratings for lighting-related factors, suggesting better lighting design or conditions in those areas.

When asked about their overall satisfaction with the indoor environment, responses varied widely across floors. The 1st

floor exhibited a higher mean overall satisfaction score of 4.6 (SD = 1.2), while the 2nd floor showed significant polarization, with a mean score of 3.8 (SD = 1.4) and a mix of highly satisfied and highly dissatisfied occupants.

The results highlight the importance of considering occupant feedback and perceptions when evaluating and improving indoor environmental quality in educational facilities. Specific areas of concern, such as thermal comfort on the 3rd floor, noise issues across multiple floors, and lighting quality problems, were identified and may warrant further investigation or remediation efforts.

V. DISCUSSION

The descriptive statistics revealed considerable variations in occupant satisfaction levels for various IEQ parameters, as evidenced by the relatively high standard deviations. This highlights the importance of addressing localized issues and accounting for diverse occupant perceptions within the building.

The inferential analysis confirmed that overall IEQ satisfaction differed significantly across floors, with the 3rd floor exhibiting lower mean scores compared to the 1st and Ground floors. This aligns with the observation that the 2nd floor had a higher incidence of thermal comfort, air quality, acoustics, and lighting quality issues reported by occupants.

An important insight into the indoor environment was revealed by the occupant satisfaction survey results. The findings highlighted significant variations in satisfaction levels across different floors and IEQ parameters, suggesting areas for potential improvement.

Thermal Comfort Perceptions

The polarization of thermal comfort perceptions on the 3rd floor suggests potential issues with temperature control, ventilation effectiveness, or insulation in certain areas. Factors such as occupant density, equipment loads, and solar heat gains due to the building's orientation may contribute to these discrepancies. In contrast, the 1st and 2nd floors exhibited more consistent ratings in the neutral to satisfactory range for thermal comfort parameters.

The wide range of thermal comfort ratings on the 3rd floor suggests localized issues that may stem from factors like uneven temperature distribution, ineffective ventilation, or inadequate insulation in certain areas. Addressing these discrepancies should be a priority to ensure consistent thermal comfort conditions for all occupants.

Air Quality Concerns

The presence of odours reported across multiple floors indicates potential sources of indoor air pollutants that require further investigation. These could include inadequate ventilation rates, off-gassing from building materials or furnishings, or issues with the HVAC system. The more positive air quality ratings on the ground floor suggest that improvements may be achievable through targeted interventions.

Air quality perceptions were mixed, with ground floor generally receiving positive ratings while 1st floor had more negative feedback. The presence of odors reported across multiple floors suggests potential sources of indoor air pollutants that should be investigated, such as inadequate ventilation, off-gassing from materials, or issues with the HVAC system. Maintaining good indoor air quality is crucial for occupant health, well-being, and cognitive performance in educational settings.

Acoustics/Noise Discomfort

The lower mean satisfaction scores for noise from outside and the inability to have private conversations, particularly on the 2nd floor, highlight the need for effective sound insulation measures and strategic placement of noise-sensitive areas. Exploring sound-absorbing materials and implementing noise control strategies could contribute to improved acoustic comfort.

Implementing effective sound insulation measures, strategically locating noise-sensitive areas, and exploring sound-absorbing materials could help mitigate these challenges and enhance acoustic comfort within the educational environment.

Lighting Quality Variations

Despite the generally positive mean satisfaction score for lighting quality, the frequent reports of glare and discomfort on the 2nd floor suggest potential deficiencies in lighting design or control systems in specific areas. Conducting detailed lighting assessments and implementing corrective measures could enhance visual comfort and occupant well-being.

Overall IEQ Satisfaction

The varying levels of overall IEQ satisfaction across floors underscore the importance of addressing specific issues identified in the survey. Floors with lower overall satisfaction ratings, like the 2nd floor, may require more comprehensive interventions to improve multiple IEQ aspects simultaneously. Conversely, floors with higher satisfaction levels can serve as benchmarks or reference points for best practices in IEQ design and management.

It is important to note that IEQ perceptions can be influenced by various factors, including individual preferences, expectations, and situational contexts. Nonetheless, occupant feedback provides invaluable insights into the real-world performance of buildings and can guide targeted improvement strategies to enhance the overall indoor environment quality for occupants.

Implications and Recommendations

To address the identified issues and improve overall IEQ, a holistic approach integrating occupant feedback, building

assessments, evidence-based strategies, and targeted interventions is recommended. This may include enhancing temperature control and ventilation systems, addressing potential sources of indoor air pollutants, implementing noise control measures, and optimizing lighting design and control systems. Continuous monitoring, regular maintenance, and proactive measures to address identified issues can contribute to creating healthier, more comfortable, and productive learning environments.

Collaboration between facility managers, building professionals, and occupants is crucial in implementing effective solutions tailored to the specific needs and challenges of the building. Prioritizing IEQ in educational settings is essential, as it directly impacts the well-being, comfort, and learning experiences of students and staff. Future research could explore the impact of improved IEQ on occupant productivity, health, and educational outcomes, as well as the cost-effectiveness of various IEQ improvement strategies. It would also be beneficial to conduct longitudinal studies of IEQ interventions over time to gain insight into the sustained benefits and challenges that such efforts may present.

Overall, this study contributes to understanding of IEQ perceptions and challenges of educational facilities, emphasizing the need for continuous monitoring, data-driven decision-making, and proactive measures to create optimal indoor environments that foster learning, productivity, and occupant satisfaction.

VI. CONCLUSION

This study aimed to evaluate the IEQ of an educational building by conducting an occupant satisfaction survey across multiple floors. The results revealed significant variations in occupant perceptions and satisfaction levels for various IEQ parameters, highlighting the importance of addressing localized issues and accounting for diverse occupant experiences within the building.

The descriptive statistics and inferential analysis confirmed that overall IEQ satisfaction differed significantly across floors, with the 2nd floor exhibiting lower mean scores compared to other floors. This finding aligns with the observation that the 2nd floor had a higher incidence of thermal comfort, air quality, acoustics, and lighting quality issues reported by occupants.

Thermal comfort emerged as a critical concern, with substantial variations in ratings on the 2nd floor, suggesting potential issues with temperature control, ventilation effectiveness, or insulation in specific areas. Addressing these discrepancies should be a priority to ensure consistent and comfortable thermal conditions for all occupants.

Air quality perceptions also varied considerably, with odour issues reported across multiple floors. This indicates the need for further investigation into potential sources of indoor air pollutants, such as inadequate ventilation rates, off-gassing from materials, or issues with the HVAC system. Implementing targeted mitigation strategies and improving ventilation could enhance indoor air quality and occupant well-being.

Noise disturbances from external sources and the inability to have private conversations were identified as significant concerns, particularly on the 3rd floor. Effective sound insulation measures, strategic placement of noise-sensitive areas, and the exploration of sound-absorbing materials could contribute to improved acoustic comfort and minimize distractions in learning environments.

Lighting quality received mixed reviews, with glare and discomfort being frequently cited issues on the 3rd floor. Conducting detailed lighting assessments and implementing corrective measures, such as adjusting lighting levels, reducing glare sources, or improving uniformity, could enhance visual comfort and occupant satisfaction.

The study highlights the importance of considering occupant feedback and perceptions in evaluating and optimizing IEQ in educational facilities. Continuous monitoring, regular maintenance, and proactive measures based on occupant feedback can contribute to creating healthier, more comfortable, and productive learning environments.

Ultimately, this study underscores the significance of prioritizing IEQ in educational settings, as it directly impacts the well-being, comfort, and learning experiences of students and staff. By addressing the identified issues and continuously striving to enhance the indoor environment, educational institutions can create optimal conditions for learning, productivity, and overall occupant satisfaction.

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