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ROLE OF VISUAL COMFORT FOR CHILDREN IN LEARNING ENVIRONMENT

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Abstract:
Lighting is a fundamental component of quality of learning conditions and in particular school buildings where children spend a significant part of their time in visually stimulating activities like reading, writing, drawing, and computer use. Visual comfort refers to visual system contentment that is not associated with strain or discomfort.

The qualitative and analytical methodology will be applied in the research to evaluate the significance of visual parameters of comfort in the learning environment of children. The research methodology involves literature search of national lighting standards to establish the benchmark values of such critical parameters as illuminance, daylight factor, useful daylight illuminance (UDI), glare control, correlated color temperature (CCT), color rendering index (CRI) and uniformity ratio. Learning environment has been broken down into formal and informal environment to enable comparative research of natural and artificial lighting environment. User-centric research is also applied to the current study in examining the observation study and behavioral response of children to conclude on the suitability of the proposed lighting parameters. The findings are synthesized to come up with design parameters that are applicable in the Indian schools.

Keywords: *Visual comfort, Childrens learning, Lighting Parameters, Illuminance, Daylight factor, Glare control, Indian Schools, CCT, CRI*

Aim:
To research and examine the parameters of visual comfort as a tool of improving the learning performance, visual health and the general well being of children in the learning settings.

Fig1. The image shows how uncomfortable visual conditions can affect children alertness and engagement in classroom activities

Introduction & Background:
Since children spend 6-8 hours daily within school premises in India with most of the tasks taken up being

reading textbooks/ writing notes/ drawing diagrams and using digital devices more and more, the light is one of the determinants of the best learning qualities to be achieved. They are frequently defined by the unsophisticated mixture of natural light through expansive open windows and the use of artificial light such as fluorescent tubes, most of them just exist in poor conditions, such as flickering lighting, excessive glare created by the tropical sun or obscure areas by obsolete infrastructure and a general lack of awareness of standards.

The levels of illuminance (lux), availability of daylight (daylight factor and UDI), glare control, CCT (K) and CRI are but a few of the parameters of lighting that can be important in visual comfort that can be described as a contented visual system that is free of strain, discomfort or fatigue. Children have particularly sensitive visual systems because young children (younger than 300 lux) have immature visual systems and therefore, exposure to little light (below 300 lux) (IS 3646) results in eye strain and increased myopia development, and bright glare causes attention diversion and thinking impairment.

Research also states that poor lighting conditions exacerbate issues in Indian overcrowded classrooms by slowing reading rates by up to 1520 percent (Peter R. Boyce Human Factors in Lighting) and diminishing attention span, inducing mood swings, and leading to poor performance in the long run. However, studies that prove the enhancement of learning performance in optimal conditions prove that appropriately set up lighting enhances better concentration, faster performance of duties, and even emotions. Through qualitative and analytical approaches to the study of children and their response behavior in formal (classrooms) and informal (activity areas) space workplace, this research fills these gaps by analyzing national standards (including BIS IS 3646) and focusing on user centric observations of children in formal and informal spaces related to behavioral responses.

Methodology:

The approach is qualitative, analytical, and user-centric and divided into several steps. This has aided in the realization of not just the technical side of lighting but also the experience and reaction of the users especially the children to the various lighting conditions in the learning conditions. The methodology will help to integrate the theoretical knowledge with practical observations so that there will be a complete understanding of visual comfort.

This research is majourly guided by five research questions:

1. What is the visual comfort variable effect on the performance of children in learning settings and their visual health?
2. How does the level of illumination in classrooms affect the ability of children to concentrate and perform better?
3. What is the impact of availability of light in daylight on visual comfort in formal and informal learning environments?
4. Are evenly distributed lights useful in enhancing the visibility of tasks and reducing eye strain in classrooms?
5. Do we have enough lighting standards and guidelines that can be used to provide visual comfort in the Indian schools?

And followed by five steps :

1.Literature Review

An extensive examination of the national and international standards and the research studies was conducted to develop a solid theoretical foundation of the study. This involves the analysis of the BIS standards (IS 3646) and the National Building Code (NBC 2016) as well as the Energy Conservation Building Code (ECBC). Besides these, international daylighting research was also consulted to get international insight into educational lighting design. Due to this review, important lighting parameters were recognized, such as the illuminance (lux), daylight factor, useful daylight illuminance (UDI), glare index, correlated color temperature (CCT) and color rendering index (CRI). These parameters are used as the benchmark values to analyze the visual comfort of the classroom settings and to be used in the further analysis of the study.

Category	Space Type	Parameter	Value
Daylight Requirement	Educational Buildings	UDI (ECSBC)	40%
Daylight Requirement	Educational Buildings	UDI (ECSBC+)	50%
Daylight Requirement	Educational Buildings	UDI (Super ECSBC)	60%
Building Area Method	University & Schools	LPD (ECSBC)	11.2 W/m²
Building Area Method	University & Schools	LPD (ECSBC+)	9.0 W/m²
Space Function	Classroom / Lecture	LPD	10.9–13.7 W/m²
Space Function	Classrooms	LPD	11.0–13.8 W/m²
Space Function	Laboratory	LPD	12.1–15.1 W/m²
Space Function	Library Reading	LPD	9.2–10.0 W/m²
Space Function	Library Stacks	LPD	14.6–18.3 W/m²

Table 1. ECBC 2024 – Educational Buildings Lighting Table. Source: ECBC code

Space Type	Illuminance (Lux)	Quality Class
Classroom / Teaching Space	200 – 300 – 500	Class 1
Lecture Theatre	200 – 300 – 500	Class 1
Seminar Room	300 – 500 – 750	Class 1
Laboratory	300 – 500 – 750	Class 1
Library	200 – 300 – 500	Class 1
Art Room	300 – 500 – 750	Class 1
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Table 2: IS 3646 (Part 1): 1992 – Educational Illuminance Table. Source IS3646 (part1).

Parameter	Requirement
Ceiling Reflectance	High (to improve illumination)
Minimum Illuminance Ratio (General Area)	≥ 1/3 of task area
Uniformity Ratio (Adjacent Areas)	≤ 5:1
Minimum Average Illuminance	≥ 1/8 of recommended value

Table 3. Reflectance and Illuminance Requirements.

Parameter	Value
Glare Rating Scale	0 (No glare) to 6 (Intolerable)
Acceptable Glare Range	1.5 – 2.2 (Moderate comfort)
Maximum Luminaire Angle	≥ 45° (to reduce direct glare)

Table 4. Glare Control Requirements

Lamp Type	Luminance Range (cd/m²)	Shielding Angle (Class 1 / 2 / 3)
Fluorescent Lamps	$< 2 \times 10^4$	10° / 0° / 0°
Fluorescent Diffused	$2 \times 10^4 – 5 \times 10^4$	15° / 30° / 0°
Sodium Vapour / High Pressure	$> 5 \times 10^4$	30° / 15° / 10°

Table 5. Recommended Shielding Angle

2.User Analysis

The user centric observations were done in an attempt to find out how the various lighting conditions reacted among students in the classrooms. The stage addresses the behavioral reactions to the learning activities like the level of comfort, concentration and visual comfort. The observation to be made is the reaction of students to poor lights like eye strain, loss of concentration or even the discomfort of glare. Likewise, the positive reactions like increased concentration, improved sitting, and more involvement are reported in the bright rooms. The current analysis demonstrates the role of designing the lighting systems not only in the technical right way but also user-friendly and comfortable.

3.Built Environment Analysis

This step looks at the physical features of the classroom which manipulate the conditions of lighting. It involves geometry of the classroom, orientation, dimension, and location of openings, and reflectance quality of the material applied on the space. The classroom design influences the distribution of light in a classroom directly. Indicatively, daylight can be enhanced through proper orientation and uniformity heightened through proper window design, and glare minimized. Light-colored walls and ceilings are some of the materials finishes that can be used to enhance better reflection of light, which enhances overall brightness. Also, the artificial lighting fixtures are evaluated in terms of the type and design to provide even lighting effects and visual comfort.

4.Comparative Study

In order to learn the variations in traditional and modern learning environment, a comparative research was conducted. Conventional classrooms primarily depended on natural lighting and could not control the lighting conditions and tended to create unequal visual comfort. Modern classrooms, on the contrary, employ an elaborate artificial lighting and digital technologies like smart board. Although the modern systems offer more control and

consistency, they also create other problems like glare on the screen and excessive reliance on artificial light. This comparison aids in establishing the merits and shortcomings of both methods and gives information of how to have a balanced design of lighting.

5.Architectural adaptions

At the last phase, all findings of each of the previous phases are synthesized in order to formulate architectural solutions to enhance visual comfort in the classroom. This entails taking theoretical information, case studies observation, and user response into practical design resolutions. This is centered in the aspect of achieving the balance between natural and artificial lighting, minimising glare as well as ensuring that there is a uniform distribution of light in the classroom. The strategies also take into account the issues of energy efficiency and the comfort of the user and thus they can be used in the real world scenario in Indian schools. This level will be the foundation of design suggestions made in the research.

User Perception Survey:

In order to get the actual effect of the visual comfort on children in learning classrooms, a user perception based survey was carried out. The survey will target students between the age range of 4-10 years since they are very sensitive to lighting conditions because of their developing eyesight. The research adopts a questionnaire approach and is backed by observational information and secondary research work so that a sound and detailed picture of user experience can be achieved.

The survey was conducted to assess the most important parameters of visual comfort such as the illuminance level, glare, consistency of light distribution, and the preference of natural and artificial lighting. The sample size studied was 20, and the data were gathered as a result of an indirect interaction with parents, teachers, and people who were close to the classroom setting. To see the influence of the lighting conditions on the comfort of students, their concentration and visual performance, the questionnaire also contained both objective and perception based questions.

The following tables and charts help in identifying major comfort issues, user responses, environmental factors, and architectural strategies that influence children concentration, behavior, and overall learning experience in the context of composite climate.

- Climate Responsive Analysis Table

  Composite climatic conditions have significant effect on the visual comfort in the classroom environment.The combination of intense summer sun, bright light and irregular light penetration can be uncomfortable for the eyes of children. The table below shows some of the key visual comfort concerns, their visual effects, and appropriate architectural solutions to enhance classroom lightings

CLIMATIC ISSUE	VISUAL IMPACT	SUGGESTED SOLUTION
Harsh Afternoon Sunlight	Excessive glare	Louvers/blinds
Deep classrooms	Dark rear zones	Uniform LED layouts
West facing openings	Heat gain & glare	Shading devices
Uneven daylight	Visual Fatigue	Light Shelves

Table 6. Climate responsive analysis table. Source: From survey.

- Classroom lighting assessment table

  The quality of classroom lighting significantly contributes to the visual comfort, concentration and learning efficiency of children. The assessment table below presents and compares the major key lighting parameters observed in classrooms and compares the overall lighting performance in terms of visual comfort with the user response according to the standards.

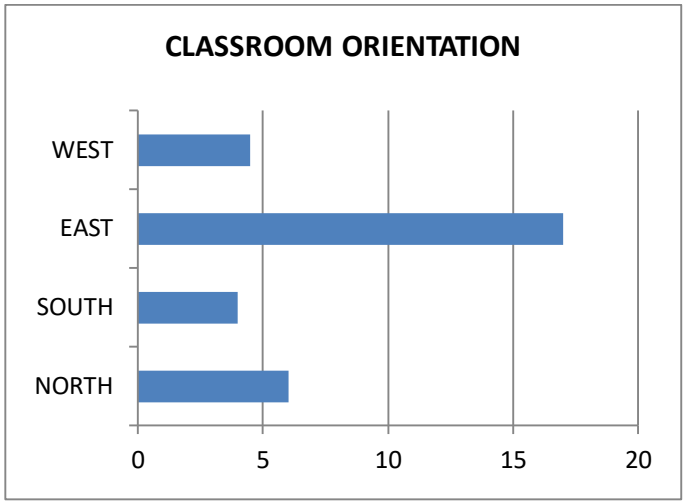
Parameter	Observed condition	Impact of visual comfort	Performance evaluation	Suggested improvement
Daylight availability	Uneven daylight penetration in deeper classroom areas	Causes dim rear zones and reduced visibility	Fair	Increase window area and use light shelves
Glare control	Excessive glare near window during afternoon hours	Causes eye strain and distraction among children	Poor	Provide louvers, blinds, or diffused glazing
Uniformity of light	Brightness concentrated near openings	Uneven lighting affects concentration and comfort	Fair	Use balanced lighting layout and reflective surfaces
Artificial lighting	LED and tube lights used during daytime	Supports visibility but increases dependence on artificial lighting	Good	Integrate daylight responsive lighting systems
Classroom orientation	East and west facing openings observed	Harsh sunlight and thermal discomfort	Poor	Prefer north oriented
Surface reflectance	Dark furniture and wall finishes absorb light	Reduces overall brightness in classroom	Fair	Use light coloured reflective finishes
Lighting flexibility	Fixed lighting system with no dimming control	Difficulty adapting lighting for different activities	Fair	Introduce adaptive or dimmable lighting system

Table 7. Classroom lighting assessment table.Source From survey

- Table of visual comfort parameters for play school learning environment

Parameter	Recommended value/unit	Idea range for play school	Measuring devices	Purpose
Illuminance level	Lux (lx)	300-500 lux	Lux meter	Measures brightness on work surface
Daylight factor	Percentage (%)	2%-5%	Daylight meter / simulation software	Measures natural daylight availability
Useful daylight illuminance	Lux (lx)	100-2000	Simulation software (radiance dialux)	Evaluates useful daylight levels
Glare index	UGR value	Below 19	Glare meter/HDR camera	Measures visual discomfort due to glare
Correlated color temprature	Kelvin (K)	3000K-4000K	Spectrometer/light meter	Determines warmth/ coolness of light
Color rendering index	CRI value	Above 80	Spectrometer	Measure color accuracy under lighting
Uniformity ratio	Ratio	Minimum 0.6	Lux meter grid analysis	Measures even distribution of light
Window to floor ratio	Percentage (%)	15%-25%	Measuring tape / CAD analysis	Assesses daylight penetration
Reflectance value	Percentage (%)	Wall: 50-70% Ceiling: 70-90%	Reflectometer	Measures surface light reflection
Artificial lighting power density	W/m sq	7-11 W/m sq	Energy meter	Measures lighting energy efficiency

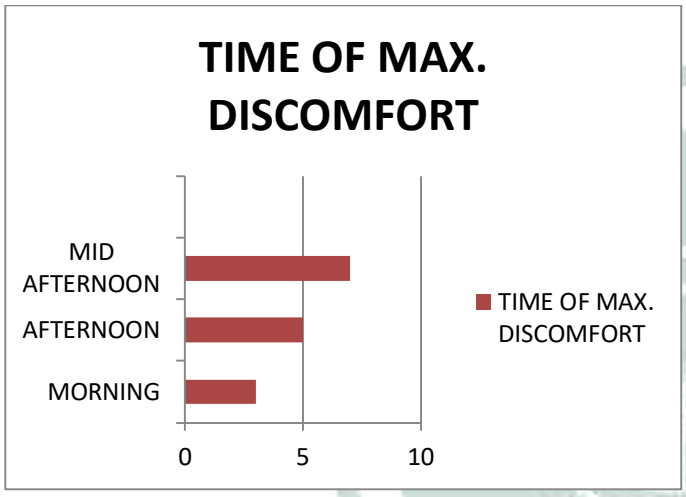
Table 8. visual comfort parameters for play school learning environment. Source: From survey



Analysis: as seen in the graph, the direction of most classrooms is towards the east direction. The classroom will be oriented east to get good morning sun, and west to avoid to glare of the afternoon sun. there are fewer classrooms that face north, but these classrooms offer more consistent and pleasant daylight.

Inference: The orientation of classrooms directly influence the quality of daylight and visual comfort in learning environments in the classroom

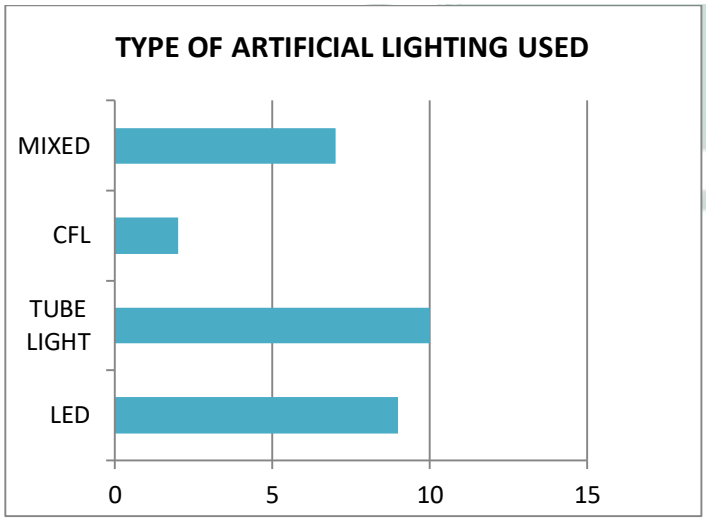
Graph 1. Type of artificial lightings used. Source: From survey.



Analysis: The graph shows that most of the discomfort with vision is experienced during the afternoon and midday when there is an excessive amount of sunlight and glare.

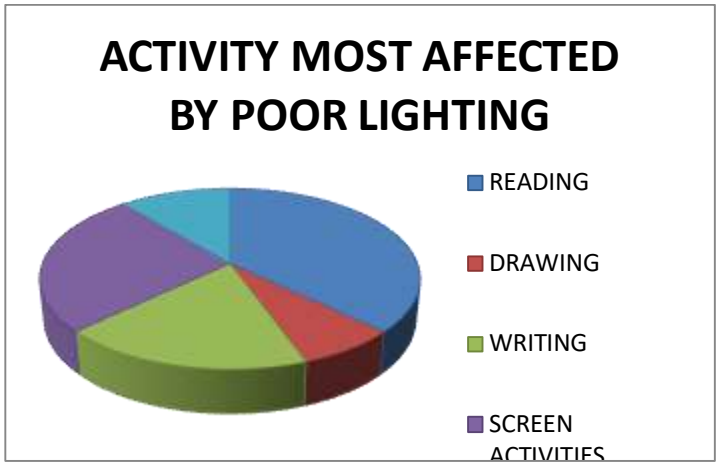
Inference : The glare and discomfort caused by intense sunlight in bright daylight hours, especially during peak sun hours, impact childrens focus and wellbeing.

Graph 2. Time of max discomfort. Source: From survey.



Analysis: The graph indicates that LED/Tube light is the most frequently used artifical light source in classrooms followed by CFL light.

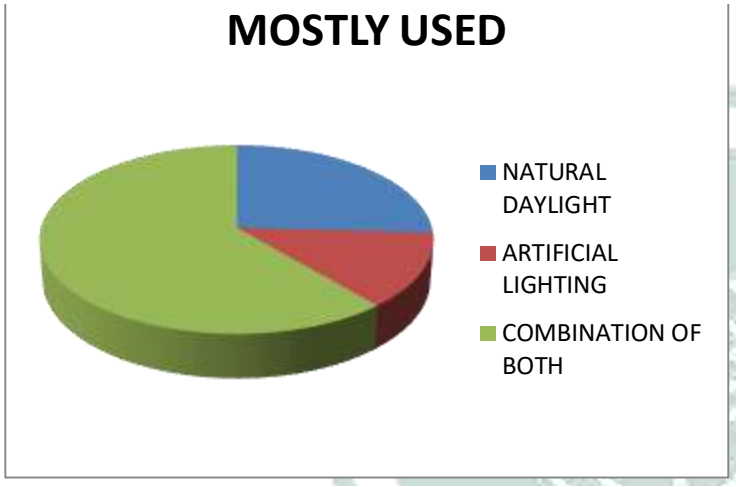
Inference: LED and tube lighting systems are becoming more of an integral part of modern classrooms to ensure proper lighting.



Analysis: As seen from the pie chart, the reading, writing and screen related activities are most impacted by poor lighting conditions.

Inference: Illuminating conditions and glare affects visual tasks that involve concentration.

Graph 4. Activities most affected by poor lightings. Source: From survey.



Analysis: The chart also shows that a lack of light has a negative effect on children's visual engagement, particularly when reading and using digital learning tools.

Inference: Children will be visually comfortable and efficient in learning when lighting conditions are balanced.

Graph 5. Type of lighting mostly used. Source: From survey.

1.User Analysis:

User Groups

Students between the ages of 4-10 years are regarded as the main consumers in this study, and they spend a good part of their day in classrooms carrying out activities that demand visual activities. The teachers are also the secondary users and require proper conditions of light to conduct effective teaching and communication.

Behavioral Observations

Survey and observational analysis unveils that the lighting conditions directly affect the student behavior and performance. In a low light , the students wil suffer eye tension, exhaustion, and a loss of concentration. To overcome poor visibility, they tend to assume poor postures such as bending forward or squinting. Conversely, the brightly lit rooms lead to enhanced interaction, concentration and participation. As lighting is evenly spread throughout with no glare, students seem to be more comfortable and focused.

Impact of Visual Parameters

The various lighting parameters have different effects on user experience. Darkness brings about visual discomfort and eye strain whereas too much brightness or glare causes distraction and inability to focus. Low degrees of

uniformity cause different levels of visibility in the classroom, which impacts the students sitting at various places. On the same note, poor color temperature (CCT) may affect the mood and alertness of people and thus it is a significant consideration in learning environment design.

Key Insight

The analysis has clearly shown that children are sensitive to lighting conditions when compared to adults. Their visual systems are still in progress and thus they need to be provided with stable, uniform, and light free at the glare level environments. This renders visual comfort one of the most important design specifics in learning architecture.

Built environment analysis:

The built environment is significant in the quality of lighting in classrooms. The depth and the height of the classroom geometry determines directly the penetration of daylight. It is also noted that classrooms with greater depth get less natural lighting particularly at the back thus it is hard to have uniform lighting. Ideally, the depth of the classroom is not to be more than twice the height of the window to allow enough daylight distribution.

Another important factor is orientation. Northern facing classrooms have diffused and uniform daylight which is perfect in visual comfort (IS 3646 Part 1). East and west orientations on the other hand tend to cause harsh sun rays and glare mostly in the morning and afternoons. The area and the location of openings also affect the entry of light into the space. Well planned windows with the right sill height can improve the day lighting penetration and also reduce glare.The light penetration is also increased by the reflectance of the material used. Light colored walls and ceilings contribute to light reflections, which enhances general brightness and homogeneity, and a darker surface absorbs light and gives rise to an environment that is darker (IS 3646 Part 1). When artificially illuminated systems are well planned in a regular grid system, it can supplement natural light and provide even illumination through the classroom (IS 3646 Part 1).

Moreover , the implementation of artificial lighting system is mandatory to ensure the stable levels of lighting during the day. Well planned lighting plans will result in eve lighting and minimized shadows and glares. Digital technologies are also present in modern classes, and in this case, one should pay attention to the lighting to prevent reflections and screen glare.

The built environment of educational facilities must be done in a holistic manner, taking into account the environment and the needs of the users. A prepared classroom with the light balance, artificial lighting, space planning, and choice of material, spatial planning of material could contribute greatl to the visual comfort and subsequently, students begin to achieve higher learning outcomes and wellbeing.

Learning environment: Then and Now:

Classroom Learning Environments.

The main idea of traditional learning environment was designed as a more passive architecture where the natural daylight and ventilation contributed significantly to the creation of the inner environment. The general design of the classrooms was to create large windows, high ceilings and few internal barriers so that daylight can enter the classroom, give a general light. The orientation and window placement were in most instances taken to ensure that daylight is made as full as possible without artificial systems.

Fig 2 Showing traditional learning environment. Source;Google

But regardless of these merits, the use of traditional classrooms had little power to control lighting. The quality and the intensity of light was highly different at different seasons of the year and weather conditions. Direct sunrays were known to cause glare particularly in classrooms that faced the east or west and overcast weather led to low light. Moreover, the design of the light was not very much thought-out, and the brightest spots were placed by the windows, and the darkest ones were further in the classroom. Consequently, not all students were comfortably positioned to see the projector, which led to discomfort to the students sitting in various sections of the classroom. This powerlessness had a habit of lowering focus and learning ability.

21st-century Learning Environments.

The artificially lit and computer-mediated learning environments have developed to a greater extent in modern learning settings. The use of the LED lights in the classroom nowadays is a common feature and is organized in a systemized pattern whereby, the light levels can be easily controlled and the light itself is evenly distributed throughout the classroom. The use of smart boards, projectors, and digital screens have also remodeled the design of classrooms and their usage.

Fig 3.Showing 21st century learningenvironment

These environments have a number of benefits, such as the uniformity of lighting conditions during the day, a smaller reliance on external processes, such as weather, and the possibility of controlling the level of light in relation to a particular task. The ability to adjust the temperature of the lights and the ability of dimming lights is also used to make the lighting more flexible and more comfortable to the eyes when performing various learning tasks.

But new challenges are occurring in the modern classrooms, too. Screen glare and reflections are some of the issues that come with the increased use of digital screens and may result into visual discomfort, unless effectively handled. Moreover, overuse of artificial lighting may result in less exposure to natural daylight which is significant to keep circadian rhythms and well-being. Even ill designed artificial lighting systems may lead to glare or uneven light distribution, which is why it is necessary to carefully design and integrate.

Adaptive Learning Environment.

Adaptive learning settings have been highly transformed with the incorporation of sophisticated artificial lighting systems and electronic technologies. The modern day classrooms are usually equipped with LED lighting fixtures which are designed in systematic ways enabling control of the level of illumination and even distribution of light throughout the room. The addition of smart boards, projectors and digital screens has also changed the design and usage of the classroom even more.

These environments have various pluses such as uniformity of lighting during the day, lower reliance on other conditions such as the weather and the flexibility of changing the level of lighting into a particular task. A flexible color temperature feature and a dimmable lighting system are some of the features that make the product flexible and more comfortable to the eye during various learning activities.

Nevertheless, new challenges are also noted in modern classes. The more frequent utilization of digital screens also creates such problems as glare and reflections on the screens that may lead to the visual discomfort without effective coping strategies. Moreover, overdependence on artificial lighting may result in a decrease in exposure to natural daylight, which is significant in terms of preserving circadian rhythms and the general wellbeing. Even in case of poorly designed artificial lighting the result may be glare or uneven lighting, which is why it is important to design and integrate the artificial lighting systems carefully.

Comparative Analysis

The evaluation of modern and traditional learning environment shows that there is a definite change in the natural and passive system to a controlled and technology-driven system. Conventional classes, despite their environmental sensitivity and efficiency in terms of the use of energy, failed to control the lighting conditions and provided mixed visual comfort. Modern classroom, on the other hand, offers more control, consistency, and flexibility, so that the lighting conditions do not vary in accordance with outside influences.

Nonetheless, there are also some trade-offs to this change. Although the current systems enhance the control and uniformity, it tends to inhibit the natural daylight that is necessary to both the eye and psychological well-being. The traditional systems were less controlled but they gave a closer relationship to the natural light and outdoors conditions.

Thus, it can be proposed that none of the approaches can be considered completely adequate. A balanced approach of using natural daylight systems and artificial light systems provides the best learning environment. When it comes to integrating the strengths of both strategies in the use of daylight to achieve its quality and sustainability, and artificial light to achieve its control and consistency, classrooms that would benefit students as far as the visual comfort, improved learning performance, and the overall wellbeing of the students are concerned can be developed.

Architectural Interventions

According to the analysis and results of the survey, it is possible to develop several architecture solutions to enhance visual comfort in classrooms. North-facing windows, light shelves, and clerestory openings are some of the daylighting strategies that can be used in the even distribution of natural light. The control of glare is possible with the help of shading devices such as louvers, blinds, and diffused glazing.

The artificial lighting is to be planned in terms of the LED panel lights in homogenous grid, and the task lighting on blackboards. The choice of material is also a consideration whereby the reflective surfaces could help in the distribution of light and matte finishes could be applied to avoid glare. The spatial planning must be in a way that the desks are facing the window end and the blackboard facing the windows is not in the way of the direct light. Also, efficient and comfortable lighting systems can be made smart with adaptive controls.

Conclusion

The research has put it clear that the element of visual comfort is one of the basic elements in creating effective learning conditions, particularly in the case of the children whose visual systems are not yet developed. By incorporating the elements of literature review, survey based analysis and built environment assessment, we get to understand that lighting is not a simple functional necessity but a very important aspect that affects the health of students, their concentration, and the performance in general.

According to the results of the survey, many of the classes fail to achieve the necessary level of visual comfort, especially when it comes to even lighting distribution, glare suppression and a sufficient level of illumination. Problems like over-brightness in front of the window, dark spots in the background and inconvenience due to glare were also prevalent. These states cause not only visual strain and fatigue but also have negative impacts on the ability of students to concentrate, learn and understand learning activities.

The study, by placing the perception of the users with the set standards of IS 3646 and ECBC, confirms that it is not impossible to create classrooms that are both comfortable to the eye and energy efficient. The visual conditions can be made much better through the help of the architectural interventions like proper orientation, optimal design of the windows, application of reflective materials, and even lighting layouts.

To sum it up, visual comfort in classrooms is not only a technical issue, but also a design problem. A bright learning space would help students to have better visual health, cognitive, and well being. Consequently, visual comfort has to be one of the primary parameters that architects and designers should focus on when designing an educational building, especially when the environment of an Indian school is considered, where the climatic conditions and infrastructure difference significantly.

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