Evaluation of The Effects of Natural Lighting and Ventilation on Children Cognitive Development and Academic Performance: A Literature Review

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Abstract- ***This study looks at the effects of natural lighting and ventilation on children's cognitive development and academic achievement. Recent study has shown that exposure to natural light improves cognitive skills such as memory recall, attention span, and information processing, all of which lead to better academic achievement. Furthermore, proper ventilation is vital in maintaining indoor air quality, which is necessary for students' alertness, attention, and overall well-being. The study examined diverse classroom settings to determine how differing levels of natural light and airflow affect students' learning experiences. According to the findings, classrooms constructed with enough of natural light and efficient ventilation not only produce a more conducive learning environment, but also contribute to better student health outcomes by lowering fatigue and stress. This study emphasizes the necessity of optimizing classroom surroundings to improve educational experiences, recommending that educational officials and school administrators prioritize the inclusion of natural lighting and sufficient ventilation in school designs.***

Indexed Terms- ***Natural Lighting, Ventilation, Cognitive Development, Academic Performance, Classroom Environment***

I. INTRODUCTION

Children's academic achievement and cognitive development are strongly affected by their school environment. Of all environmental factors, natural air and light influences learning outcomes the most. Studies have shown that exposure to natural light makes children more cheerful, focused and cognitively active. Improvement in the air quality of a classroom with enhanced ventilation is associated with better academic performance, as reported by (Bakó-Biró et al. 2012) that higher ventilation rates in schools are associated with better student performance. Daylight is extra special because it sets the body's circadian rhythms, which you need to stay awake and attentive during school time. (Bajwa and Dogar 2024) considered the direct effect of classroom lighting quality on years' learning potential, and found a positive effect of daylight in well-lit classrooms on the academic achievement of students. This is in line with (Sadrizadeh et al. 2022) conclusion emphasizing the significance of indoor environmental quality (IEQ) in schools, that good lighting and ventilation lead to healthier children and subsequently better cognitive development. What is more, creating learning environments that incorporate nature fosters greater well-being as well as learning. According to Vakalis et al. (2021), green schools which apply natural lighting and ventilation are found to contribute in the improvement of academic performance by increasing the interest of the students and reducing the level of stress. The implementation of these factors in school buildings points however, towards an increased understanding about the necessity of a designed environment for academic achievement and general upbringing.

Natural lighting and ventilation have been proven to enhance students' cognitive growth and academic performance for many years. When educational authorities and governments decide to focus on these elements they will enhance educational experiences and achieve superior academic results for future students.

1.1 Research Aim and Objectives

Research Aim:
This study aims to evaluate the impact of natural lighting and ventilation on children's cognitive development and academic performance, and to highlight the importance of optimizing classroom environments for enhanced learning outcomes.

Research Objectives:
1. To assess the impact of natural lighting on the cognitive development and academic performance of children in classroom environments.
2. To examine the role of proper ventilation in enhancing air quality and its correlation with Improved student performance and well-being.
3. To explore the integration of natural light and ventilation in school architecture as a holistic approach to creating optimal learning environments.

II. LITERATURE REVIEW

The association between natural light, ventilation and children's cognitive performance and academic achievement is an important field for research work. Several studies have investigated how the environment factors are associated with students' well-being and learning, underscoring the important part they play in creating the perfect educational conditions.

- Natural light and Academic performance

Sunlight is one of the most beneficial environmental factors on children's cognitive development. According to research, exposure to natural light in the classroom promotes focus, Alertness, and mood all of which are important components of effective learning. (Vakalis et al.2021) found that pupils exposed to natural light performed much better on standardized tests, improving reading and arithmetic scores by up to 26% over a year when compared to students in artificially lit classes. Furthermore, kids in well-lit classrooms were more engaged, retaining their focus throughout the school day, which is critical for academic success.

Beyond academic success, natural light improves children's physical and mental well-being. Natural light exposure has been demonstrated in studies to control sleep cycles, improve attention, and reduce behavioral disorders in schools (Sadrizadeh et al., 2022). Research suggests that windows with natural light and outdoor views can improve pupils' emotional health and reduce stress (Díaz-Martínez et al., 2023).

- Ventilation and Cognitive Development

Good ventilation is really important for healthy indoor air quality and children's thinking skills and health are closely related to a healthy space inside. If the air inside is not good enough, students might find it hard to focus, be away from school a lot, and have more health problems.

Proper ventilation in schools is very important for improving cognitive skills and ensuring good health results. Ventilation lowers the concentration of pollutants in indoor air, and it can assist in protecting a healthy zoning environment. As an example, schools using increased natural ventilation have indicated that student absence is lower and breathing problems are reduced (Fernandes et al. , 2023). In addition, fresh air enhances brain function and also how much energy someone has, and these things really help students do well in school.

- Combined effects of natural lighting and ventilation

We can see that the best places for learning, which truly boost how kids' brains develop, happen when natural light and fresh air work together. Classrooms that are well-ventilated and have a lot of natural light, studies show, enable students to have better focus and be more capable when they switch between tasks. For example, when paired with good airflow, dynamic lights that adjust with the time of day may improve students' thinking skills (Vestfal & Seduikyte, 2024). Furthermore, adding green spaces to school grounds, which of course provide light and ventilation, has been tied to improved brain development in children. Exposure to green spaces has been linked to improved focus and better emotional regulation (Díaz-Martínez et al. , 2023). Research generally and

strongly backs up the idea that good lighting and enough fresh air are key parts of places that help kids learn and do well in school. When schools make these things a key part of how they design their buildings, they can really help students do better in school and have a more positive time learning.

III. METHODOLOGY

This study employs a qualitative research method, relying on a complete literature review, to evaluate how natural light and airflow affect kids' thinking skills and school success. To do this, we carefully reviewed research papers and documents that study the connection between things in the classroom, like light and fresh air, and how well children learn. The base of the research is the literature review and it sums up past studies on how environmental designs like natural light and airflow affect kids' learning, thinking, and health. The research reviews school papers and documents from subjects like environmental psychology, teaching, and building design, and it finds key plans and results on how natural light and airflow change how well kids learn. In addition, this process includes evaluating different studies.

The studies were done in many climate situations to find out if the plans worked well in those different places. Through literature analysis, this study intends to comprehensively understand how natural lighting and ventilation impact cognitive development and academic achievement. Looking at what works in design and how it helps students in a measurable way, the study looks forward to helping plan and create better learning spaces, so kids have the best environment for learning. The data gathered from the literature review will be merged so we can understand more clearly how parts of the environment like natural light and airflow can be changed in schools to help children's minds grow and help them do better in their studies.

IV. RESULT AND DISCUSSIONS

The research looks into ten studies regarding how natural light and airflow impact children's thinking and learning in school, mainly looking at what they wanted to achieve, how they did it, and what they found out. The study checks out how the design of school environments, mainly natural light and air that is clean, helps students learn and get better grades. The review looks into various answers and includes making the most of classroom design for natural light, adding natural air systems, and pushing for a healthier inside space. The discoveries explain how passive design techniques improve thinking ability, school performance, and complete student health. This study gives thoughts on how to build supportive and durable educational settings, and these settings encourage children's thinking growth and school success.

4.1 Summary of reviewed literature

S/N	Title of article	Name of author(s) and year it was published	Aim and objectives	Methodology	Result
1.	Investigating the impact of environmental factors on learning and academic achievement of elementary students: review	Abdolreza Gilavand (2016)	To assess the impact of environmental factors, mainly natural lighting on student cognitive performance	A systematic literature review was conducted by using data from major databases (e.g, PubMed, Scopus, SID,	This review discovered that natural lighting significantly improves the students' academic performance and

			and academic achievement. The objective was to guide educational planners and designers in considering lighting as an important element in creating effective learning environments	and Google Scholar). Out of 252 articles initially found, 39 of them were selected based on expert evaluation. The review covered studies from 2000 onward, and data extraction and quality assessment were done independently by two investigators	learning. Adequate lighting enhances visual comfort, it also reduces stress, improves focus and concentration, and contributes to better cognitive development
2.	A field Study of the Impact of Indoor Lighting on Visual Perception and Cognitive Performance in Classroom	Qiang Liu, Zheng Huang, Zhijiang Li, Michael R. Pointer, Geng Zhang, Zhen Liu, Hanwen Gong, Zhen Hou (2020)	To investigate on how different types of indoor LED lighting in classrooms affect students visual perception and cognitive performance. The objective was to get a better understanding on the roles of light quality and visual fatique on reading comfort, attention and alertness in real classroom settings.	A field experiment was conducted with 79 college students in a classroom under two types of lighting (tubular LED and LED panel). Six tests were conducted before and after a 2-hour study session, including color preference, atmosphere perception, the Anfimov attention test, Karolinska Sleepiness Scale (KSS), and reading comfort using three different paper colors.	Lighting considerably influenced skin tone perception and atmospheric comfort. However, no significant impact was found on attention (Anfimoy test), alertness (KSS), or reading comfort. Paper color seemed to have a stronger effect on their reading comfort than lighting. Also, there was no major viausl fatique effect that was detected after 2 hour study
3.	Influence of the	Lucas	To analyze	Field study was	Lighting levels

	thermal and lighting performance in classrooms on the cognitive productivity of students in Colombia	Arango-Díaz, Olga Lucía Montoya Flórez, Laura Rendón Gaviria, Luz Magnolia Tilano Vega, Carla Maria Zapata Rueda (2021)	how thermal and lighting conditions in classrooms influence cognitive performance (attention and executive functions) of 5th and 6th-grade students in public schools in Colombia. The objective was to assess environmental comfort factors and their correlation with learning efficiency.	made in 40 classrooms across 14 public schools in Bogotá, Cali, and Medellín (2017–2018). Used cognitive performance tests (e.g., letter cancellation and fluidity tasks), thermal and visual perception surveys, and physical measurements (illuminance, temperature, humidity). Data analyzed with correlational and hierarchical regression methods.	had a weak but statistically significant effect on cognitive outcomes, especially in semantic fluidity tasks. Students performed better in attention tests under optimal operative temperature conditions. However, relations were not always strong, possibly due to adaptation to local climate. Lighting effects varied by city and light type (horizontal vs. vertical).
4.	Effects of lighting and sound factors on environmental sensation, perception, and cognitive performance in a classroom	Wonyoung Yang & Jin Yong Jeon (2023)	The study sought to examine how lighting and sound aspects influence environmental feeling, insight, and thinking skills inside of classrooms.	For six experimental sessions, 60 students from the university were in a real classroom. Different lighting conditions included changes in illuminance, specifically at 650 lx and 1050 lx, as well as related color temperatures of 3000 K, 4000 K, and 5700 K. Sound	Lighting elements had a big impact on thinking skills, even more than noise did. Environmental perception showed cross-modal effects, but sensation did not show them. It turns out that classrooms considered perfect spots might not actually boost thinking skills.

				conditions were also manipulated. To assess cognitive performance, researchers used a working memory test and it was based on the Korean Wechsler Adult Intelligence Scale-IV.	
5.	Indoor Environmental Quality, Pupil's Health and Academic Performance	Oluyemi Olagoke Toyinbo (2017)	The goal was to check the inside environmental quality, mainly the ventilation, of primary schools and how it connects to student health and school results.	Obtained data from elementary schools that are in Finland, the USA, and also Nigeria. The temperature inside was measured, as well as CO_2, CO, moisture levels, how air moves, and details about the buildings. The surveys were given to students and principals and furthermore, the health records and academic performance information were carefully analyzed.	Not enough ventilation was tied to poor air, more breathing problems for students, a rise in school absences, and also worse results in class. When ventilation systems were better, thermal comfort and thinking results improved too. As more students occupied a classroom, the ventilation available to each student was reduced.
6.	Interaction between Thermal Comfort, Indoor Air Quality and Ventilation Energy Consumption of Educational Buildings: A	Lin-Rui Jia, Jie Han, Xi Chen, Qing-Yun Li, Chi-Chung Lee, and Yat-Hei Fung (2021)	The goal is to examine how thermal comfort, indoor air quality, and ventilation energy use work together	The study featured a thorough review of published work, looking at 148 papers from sources such as Scopus, Web of	Good ventilation really improves indoor air quality; it also lowers carbon dioxide and pollution, which helps students do

	Comprehensive Review		in school buildings, mainly to find ways of making air quality and how well students do better.	Science, and also ScienceDirect; it covered different ventilation styles like natural, mechanical, and mixed systems, IAQ measurements like CO_2, PM, VOCs, plus what all this means for well-being and grades.	better and feel healthier. When it comes to ventilation, mechanical and hybrid setups do a better job compared to only using natural methods. Bad air inside is related to lower thinking skills and also more missed days.
7.	The Role of Mechanical Ventilation in Indoor Air Quality in Schools: An Experimental Comprehensive Analysis	Ballerini, V.; Coccagna, M.; Bisi, M.; Volta, A.; Droghetti, L.; Rossi di Schio, E.; Valdiserri, P.; Mazzacane, S. (2025)	In a high school classroom, the effect of a mechanical ventilation system on air quality was tested, and the focus was on measuring CO_2, PM2. 5, VOCs, and radon.	Over a school year, a controlled study in Ferrara, Italy, made a comparison of mechanical and natural ventilation in one classroom. The sensors took readings of CO_2, temperature, humidity, PM2. 5, VOCs, and also radon both before and after the installation of MVHR or Mechanical Ventilation with Heat Recovery.	Mechanical ventilation decreased CO_2 levels by 62% on average, going from 2500 ppm to roughly 1000 ppm; this helped students be more comfortable and pay attention better. Still, not much of a difference was found for PM2. 5, VOCs, and radon. When using natural airflow, CO_2 levels would rise above 4500 ppm; however, MVHR maintained levels below 1500 ppm. Steady indoor temperature and humidity made well-being better as well.

8.	Enhancing Learning with Nature-Inspired Design in Schools	Ritika Omar, Deepti Pande Rana, Ar. Smriti Rastogi (2024)	The study looks at how including natural aspects like sunlight and fresh air in school construction might support the mental, emotional, and social growth of children.	The approach used different methods like a full review of existing writings, detailed looks at specific examples such as Nandanam Kindergarten and Fuji Kindergarten, surveys, watching what happened, and studying themes in things like light, airflow, and room layout.	When natural light and air flow are used together, the air inside is better, stress goes down, and it is easier to pay attention, be creative, and get along with people. The results of the study indicated a definite relationship between environmentally friendly design and superior areas for education. For sustainability and also for student well-being, mechanical systems that included natural features were shown to be the most effective.
9.	Architectural Indoor Analysis: A Holistic Approach to Understand the Relation of Higher Education Classrooms and Academic Performance	Vicente López-Chao, Antonio Amado Lorenzo, Jorge Martin-Gutiérrez (2019)	We aim to examine how elements inside buildings, like sunlight and airflow, affect grades in college classrooms from a complete point of view.	Using mixed methods, 796 undergraduates were surveyed with the iPEP scale; classroom elements were assessed through statistical techniques; interviews with teachers offered helpful observations.	Ventilation and also natural lighting were found to significantly predict a student's grade point average. Sunlight and scenery helped students focus in active classrooms, but in lecture halls where students were more passive, too much sunlight was a distraction. Good

					handling of natural airflow had a helpful effect on overall performance. The data supports that a complete mix of light and airflow really does improve learning results.
10.	Biophilic Design for Restorative University Learning Environments: A Critical Review of Literature and Design Recommendations	Terri Peters & Kristen D'Penna (2020)	The purpose is to discover and assess biophilic design elements, including things like natural light and airflow, that help boost health and thinking skills in university study areas.	A review of literature that was semi-structured and multi-disciplinary spanned across engineering, environmental psychology, and architecture. The studies were arranged by biophilic elements such as daylight entry, airflow, and natural resources and linked to how students did and felt.	Using natural light and good airflow helps boost how well students learn, their focus, and their good feelings. Proposed ideas are windows that users can open, different amounts of daylight, good airflow for comfort, and spaces planned to help with "prospect and refuge. " Complete biophilic plans are very effective when creating the best learning places.

Table 4.1: Summary of reviewed literature

4.2 Discussion of reviewed literature

From the literature reviewed, it is evident that environmental elements especially daylighting and natural ventilation, play a crucial role in students' learning, comfort, and well-being.

In real-life, daylighting has been proven to have a positive effect on the cognitive performance, visual comfort, and mental health. (Gilavand 2016) states that sufficient natural light decreases stress levels increases concentration and enhances educational achievement, and that healthy learning depends more on natural light, especially for the younger generation. (Yang and Jeon 2023) also reported the same in a university when existing light level and CCT had a direct relationship with the score of cognitive performance.

Some research, though, provides more complicated findings. (Liu et al. 2020), for example, reported that LED lighting types had a small effect on attention

and alertness, which may indicate that lighting can be context-dependent and be affected by other variables, such as material contrast or visual fatigue. Ventilation and indoor air quality (IAQ) is just as important. Findings by (Toyinbo 2017) and (Jia et al. 2021) concluded that poor air quality and respiratory symptoms occur indoors, and inadequate ventilation results in lower air quality and higher absenteeism, as well as decreased academic performance. Mechanical and hybrid ventilation systems have been proven to be superior to natural ventilation. According to a study by (Ballerini et al., in 2025), the introduction of these mechanical systems notably diminished CO_2 levels while simultaneously stabilizing temperature and humidity. This change not only improved comfort but also enhanced students' attention span.

Multiple studies underscore the collective advantages of incorporating natural light and ventilation in school architecture. (Omar et al. 2024) and (López-Chao et al. 2019) have confirmed that a comprehensive design approach, which includes access to daylight, cross-ventilation, and views of nature strongly correlates with improved attention span, emotional stability and academic performance among students. These findings align with biophilic design principles discussed by (Peters and D'Penna 2020), who advocate for multi-sensory environmental features such as operable windows, varied daylight, and airflow variability to create restorative, productive learning spaces.

It was observed by (Arango-Díaz et al. 2021) that regional variables and accommodation processes could have an effect on how lighting and thermal comfort interact with a student's learning performance. It is clear that putting solutions in place that consider the situation is important when building or improving schools. To summarize, the research shows a definite pattern: schools using natural light and good airflow, mainly with complete building designs, usually help students be healthier, think better, and do better in school.

CONCLUSION

This research looked at how natural light and airflow affect how kids grow mentally and do in school within classrooms. Looking at lots of studies, it becomes obvious that these outside things are key to helping kids pay attention, keep information, and succeed in their studies. It is clear that natural light makes seeing easier, helps keep your sleep cycle regular, and also lowers stress, which are all things that help you learn better. In the same way, good ventilation helps to make the air inside cleaner, which can lead to better focus, less absence from school, and a greater sense of well-being.

The article emphasizes the importance of integrating natural light and ventilation in school design for creating optimal learning environments. These elements do not only boost academic performance but also foster emotional and physical health when incorporated effectively into educational spaces. The findings reinforce the importance of biophilic and sustainable design in educational architecture and highlight the need for educational stakeholders, planners, architects, and policymakers, to prioritize these elements in future school development and renovation projects.

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