Journal of Infrastructure, Policy and Development 2024, 8(16), 10619.
https://doi.org/10.24294/jipd10619

Review

Improvement of student performance based on the lighting conditions of learning spaces: A systematic review analysis

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CITATION

Chauca M, Mendoza E, Moyano O, et al. (2024). Improvement of student performance based on the lighting conditions of learning spaces: A systematic review analysis. Journal of Infrastructure, Policy and Development. 8(16): 10619. https://doi.org/10.24294/jipd10619

ARTICLE INFO

Received: 29 November 2024
Accepted: 23 December 2024
Available online: 27 December 2024

Abstract: Lighting conditions in learning spaces can affect students' emotions and influence their performance. This research seeks to verify the influence of classroom lighting on students' academic performance under different conditions and measurement forms. The research method is based on the systematic review of research articles establishing case analyses characterizing lighting intensity and color temperature to determine ranges favorable to a higher level of attention and long-term memory. Also, this study shows relevant aspects of the cases representative of a sustainable solution and proposes a research model. The study found light intensity values between 350 and 1000 lux and color temperatures between 4000 and 5250 Kelvin that favor attention. Long-term memory reached the highest levels of measurement by analyzing different parameters sensitive to lighting conditions and questionnaires. In conclusion, it was demonstrated that an adequate light intensity and color temperature based on the greatest possible amount of natural light complemented with Light Emitting Diode (LED) light generates optimal lighting for the classroom, achieving energy efficiency in a sustainable solution and promoting student well-being and performance.

Keywords: student academic performance; lighting conditions; learning spaces; lux; Kelvin

1. Introduction

Currently, in the construction of buildings, it is very important to consider the use of light. The architectural design seeks to ensure that users find comfort inside in such a way that this emotional state favors their physical and psychological well-being in these learning environments or interiors of buildings (Almeida et al., 2018).

The lighting of the classroom environment receives daylight and artificial light, and a sustainable solution must consider both sources of lighting. In the case of artificial light, it uses energy, so an optimal solution must be sought to reduce spending and pollution generated using artificial light.

Among the United Nations (UN) sustainability objectives, we have some related to quality education, energy efficiency, lighting, and health (Tavares et al., 2021). The UN objectives find results where quality education must promote development to live in peace and harmony.

It is essential to design environments with lighting conditions that seek human comfort. These designs incorporate considerations of natural light, and lighting systems by technological development, as well as considerations of the impact of light

on the psychological conditions of users, where they continue to be inspired by discoveries (Karlicek et al., 2017).

A very important factor in the design of interior spaces is lighting. In that sense, natural light is essential, and designers focus on preserving windows where they can receive natural light in a non-direct way. There is research that shows that natural light can be used for the comfort of users, unfavorable effects can be reduced, and at the same time, greater efficiency in the consumption of electrical energy in lighting can be achieved. Research shows that some architectural designs and materials favor the use of natural light and, in this way, reduce the expenditure on electrical energy for lighting, an important aspect that has been taken more into account due to its conditions in the face of changes (Husein et al., 2020).

Making the most of natural light allows us greater energy efficiency; therefore, each interior space is designed considering this. Studies have shown that light properties, illumination, and color temperature affect the improvement of reading in students. The different lighting implementations of learning spaces lead us to the question of how lighting systems are chosen by designers of learning spaces to achieve greater academic performance. An investigation showed that there is a relationship between light factors and the oral reading level of the students; lighting and color temperature influence the students' learning (Lekan-Kehinde and Asojo, 2021).

Another important aspect of This educational scenario is the subject of students' visual health, which is necessary to consider "In the educational context, vision conditions experienced by small groups of students can be detected through school-based vision screening programs, representing an important means of detecting visual health abnormalities" (Basch, 2011).

Learning in higher education was deeply affected by the consequences caused by the pandemic due to the COVID-19 virus. Disruptive strategies are adopted for the sustainability of higher education; for this, general concepts were considered, as shown in **Figure 1**.

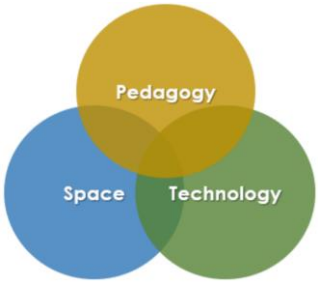

Figure 1. Three pillars of the framework for innovative classroom training (Turkey Ministry of National Education, 2021).

The educational sector promotes environmental sustainability in this sense; lighting in the classroom is essential. In this research, the following lighting variables are considered: Lighting intensity (It is the level at which light energy is received in a unit area) and color temperature of light (Reference value of how close the light is to a warmer or colder visual effect), the main objective being to determine the optimal level of classroom lighting focused on a sustainable solution with natural light and Light-Emitting Diode (LED) lighting.

This study shows the general conditions related to learning environments, such as energy and education sustainability, with special designs for learning spaces, including natural and artificial lighting, considering optical health conditions, and finally focusing on the association between the illumination conditions and the level of learning. We then analyze selected cases over this association and process some information to obtain a fine-tuning range of lux values and color temperature values for the best illumination conditions in the learning environments.

In studies carried out, we have scenarios that show relationships between lighting and the level of results tested by students for luminance and color temperature conditions, as shown in **Figure 2**.

Figure 2. The illumination level and correlated color temperatures of different luminary groups were used in the four lighting scenarios (Lekan-Kehinde and Asojo, 2021).

In this context, higher education has a great influence on technological innovation, defining strategies to mitigate the digital divide that exists in the different stages that educational institutions in the world experience.

The main objective of the research is to determine the effect of lighting conditions in learning spaces on students' performance, with a focus on a sustainable solution including natural light and LED lighting.

This work presents general information related to UN Objectives, visual health, education, and classroom lighting, as well as the method to show specific information on variables that intervene in the learning scenario under different lighting conditions, characterizing representative cases, and finally showing results, discussions and conclusions from the case analysis.

2. Materials and methods

The search for an optimal solution has led us to identify the variables involved in the research, search, and design different instruments that allow us to show the existence and level of relationships between said variables to determine the ranges or specific values of luminous intensity and color temperature that facilitate the best learning conditions.

It is important to take into consideration the following aspects:

- Learning methodology. Studies of lighting conditions and their influence on the level of learning involve considerations of learning methodology, and in that sense, those with a higher level of retention as spaces repetitions methodology and active action methodology.
- Visual health conditions. from eye fatigue to alterations in eye alignment and refraction such as astigmatism and myopia, among others.
- Classroom architectural design. The studies consider the circadian rhythm and consequently, the greater healthy use of natural light, so the design of classrooms considers up to 60% effective opening for windows and other design considerations to mitigate the harmful effects of the phenomenon of light, including the characteristics of the glass, location of the windows, color, and material of the walls and furniture.
- Light system design. The adjustable LED lighting systems allow you to control the illumination intensity and color temperature parameters of lamps, allowing you to set specific values for each type of activity.

A word cloud about all titles of articles related to this research is shown in the next figure (**Figure 3**):

Figure 3. Word cloud of all titles of articles related to this research.

2.1. Eligibility criteria

This study considers sources that meet the requirements of recent (preferably published in the last 3 years), relevant (published in high-impact specialized journals indexed in prestigious databases such as SCOPUS and Web of Science), and reliable (publications with rigorous evaluation processes between books, theses, and articles).

2.1.1. Search strategy

- Keywords. Identify the key words related to the research problem, the variables and dimensions, as well as their synonyms, using, for example, the thesaurus

using words as: Improvement, "student performance", "lighting conditions", "learning spaces", classroom.

- Search tools. On this occasion, we used Boolean operators to get closer to the most ex-act results and obtain a small sample from which we took the results with a strong relationship to the research topic.
- Publication dates. The prevailing date range for source selection was from 2020 to 2023, with some articles selected outside that range for their strong relationship with the research.
- Languages. Most of the information is in English, and in this context, this research was based on English-language sources.
- Process selection. The search uses Boolean operators. initially considered the descriptors "student performance," "lighting conditions," and "learning spaces," then we replaced "learning spaces" with the classroom. To expand the sample, we gradually removed the Boolean operator "from each compound word, adding the year or date range, "ISSN", or the name of the journal, and the Boolean operator "filetype: pdf".
- Data extraction. The search was carried out on the web for open-access sources as well as in SCOPUS and WoS, taking only the results that had the strongest relationship with the research topic.

In this context, our study considers the following topics:

2.1.2. Sustainability

Statistics show that 64% of power plants in the United States operate using coal and, in some cases, natural gas as inputs (U.S. Department of Energy, 2017).

Today, lighting can be controlled to simulate daylight, so lighting systems can be set up to be as close to natural light as possible at any time or date of the year (Vieira, 2020).

Lighting conditions with extreme levels of bright light or contrasts are most often the cause of visual health problems and emotional states of distraction in the exposed area.

The different lighting conditions at each location of the exposed area, specifically between the work area and the line of sight around it, cause difficulties in visual adaptation (Mork et al., 2019).

It is important that knowledge is easily accessible; we must also consider how to find data disaggregated from large databases or sources of information. In this sense, the public and private entities committed to the field of science in engineering education, research, and innovation must work to improve these conditions and others oriented to quality in higher education, which is developed in an environment of peace and harmony for all humanity without distinctions that affect their gender (United Nations, 2019).

The current reality of humanity, where we find critical situations of nature due to environmental pollution, global warming, and the indifference to preserving our planet, requires us to take action to protect and improve the living conditions of people and to establish policies that favor sustainability to preserve health and life on our countries (Association of Indian Universities, 2023).

2.1.3. Health

Another point is to take into consideration the health aspect, where the student may have myopia, visual fatigue, or another health condition that alters their normal conditions in classes. In the field of education, a fundamental aspect is the lighting conditions of learning spaces, these conditions may not be favorable for visual comfort, causing disturbances such as fatigue or even affecting visual health, leading to more and more statements on the subject (Cai et al., 2019).

On the other hand, in the studies related to the influence of lighting conditions on the learning level, we have different analysis models, some of which take into consideration factors such as lighting, noise, and temperature as influential factors in academic performance. We also have other more detailed models that consider, for example, we can take into account 3 learning styles according to the senses: eyes, ears, and touch., the design of the workstation, depending on the senses, light, noise, and temperature levels, or other factors such as LMS, technology, as well as the process of teaching courses to people., visual health conditions, visual fatigue, learning methodology, and other factors as influential in learning motivation, which directly influence academic performance.

2.1.4. Classroom designs

In the conditions of learning environments, a fundamental point is lighting, and an important, healthy, and sustainable strategy is the greater use of natural light. In this sense, there are studies and proposals that, for the design of environments, specifically windows, consider three variables (Window-to-Wall Ratio = WWR), as shown in **Figure 4**.

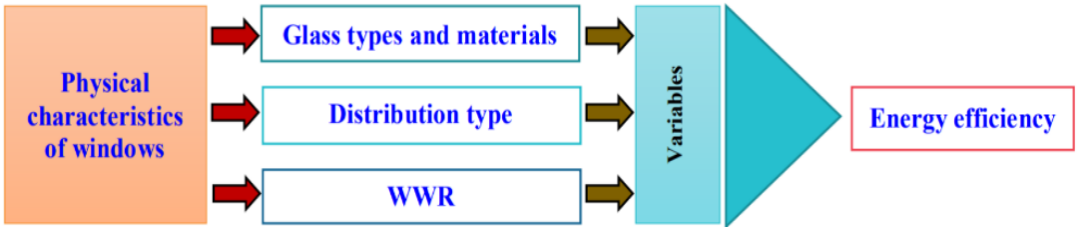

Figure 4. The conceptual framework (Ahmad, 2021).

In the cited study, it is mentioned that studies carried out on the increased use of natural light show that it is possible to reduce artificial light by 15% when we have a 50% glazing level; this natural light increases the level of comfort (Ashrafian, 2018). It is also taken into consideration that it is important to consider that to achieve greater natural light coverage, we can use an upper hatch, achieving levels higher than 60% of the covered area (Azmy, 2018).

Other studies include the circadian lighting system looking for the comfort level considering the 3-dimensional comfort zone as shown in **Figure 5**.

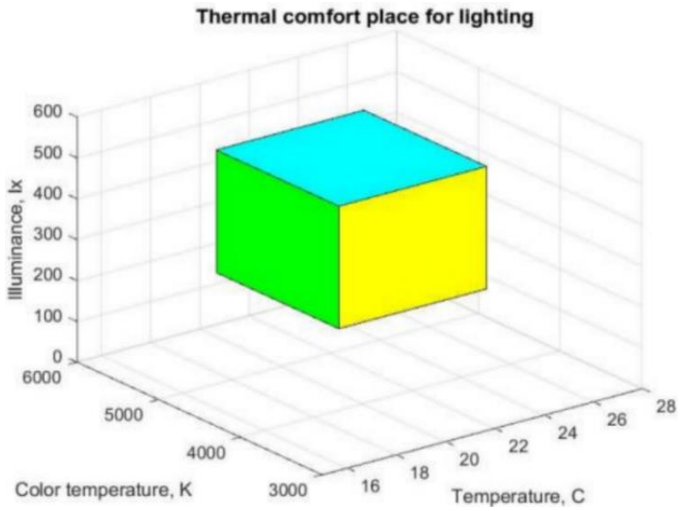

Figure 5. 3D model of thermal comfort with the connection between illuminance and room temperature (Zheliazkov, 2023).

The learning environment requires special conditions to favor its results, among which a very important one is lighting. This illumination must be at an optimum level. In related studies, evaluations have been carried out to determine the level of learning efficiency, for example, in foreign languages, as shown in **Figure 6**.

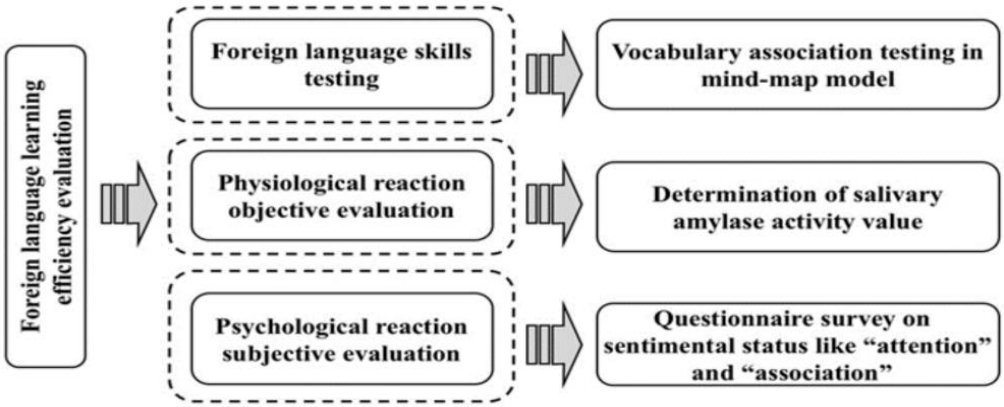

Figure 6. Evaluation modes on the efficiency of foreign language learning in different illumination environments (Liu, 2023).

The charge level of salivary amylase activity is related to stress, and in this context, we can use this algorithm:

$$N = ((A - B) \div A) \times 100\% \quad (1)$$

N = change rate of salivary amylase activity.

A = measured value before the planned lighting conditions already exists.

B = measured value when the planned lighting conditions already exist.

A partial summary of documents related to our research is as follows:

Natural light has a fundamental role in the circadian rhythm and favors people's health. A basic equation:

$$\lambda max = ((2897.88 \times um \times K) \div T \quad (2)$$

Includes wavelength and *T* temperature in Wien's displacement law, where the relationship between ambient temperature and lighting temperature is sought to be made visible. The circadian cycle relates the effect of lighting to thermal comfort; the details are shown in **Figure 7** below.

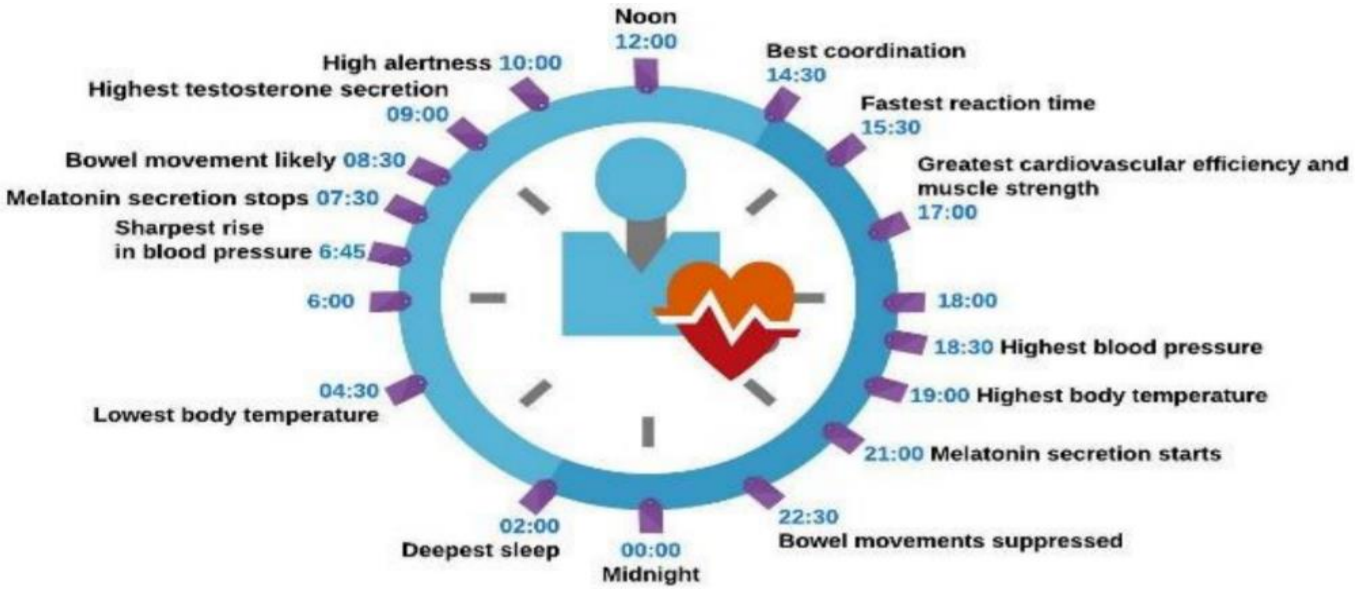

Figure 7. Circadian rhythm during the different periods of day (Zheliazkov, 2023).

2.1.5. Considerations

- The figures include fixed values and average values for each article.
- The studies take different students' conditions as the main topic for their research.
- In the context of people's health, by the influence of daylight the Well standard, and the circadian lighting design the equation used is

$$EML = L \times R \tag{3}$$

L is the visual illuminance (lux).
R is the Melanopic ratio.

$$R = (M \div V) \times 1.218 \tag{4}$$

M: total Melanopic response.
V: the total visual response.

- All studies show an increase in student and worker productivity in special lighting conditions, as well as an increase in attention and memory levels.
- The research methods are WCF tasks with ANOVA analyses, questionaries, ECG, heart rate in bump, and salivary amylase activity in qualitative, quantitative, and mixed contexts.
- The research conditions were long-term memory, attention, cognitive skills, mathematics, processing, speed, concentration, and other memory conditions.
- Studies show that natural light is very important and it's a relationship with people's health; they consider the circadian rhythm to be very important.
- Review studies consider addressing this problem through holistic research that allows for a comprehensive solution.

- All studies have objectives that are related because they seek lighting conditions to increase academic and work performance.

The systematics review considers some sources strongly related to the study, as shown in **Table 1**.

Table 1. Summary of all the related documents.

Author	Year	Type of Study or document	Problem	Explanation/Solution/Conclusion
Yuen (2023)	2023	Research article	The effect of filtered fluorescent lighting on the emotional state of students in learning spaces.	In the study, students preferred the option of filtered lighting over fluorescent lighting because it favored their emotional state.
Collier (2023)	2023	Literature Review and Pilot Study	Influence of light on the emotional state of people in offices.	Reviewing similar topics to the association between lighting satisfaction and environmental satisfaction, as well as their correlations with people's perceptions, helps the research.
Tong (2023)	2023	Research article	EEG study in offices on the influence of illuminance.	The lighting conditions for the highest student task performance and a value of 2.68, in the range of 500 to 750 lux, did affect the Plt value.
Indarto, (2023)	2023	Research article	Analysis Of Classroom Lighting Compatibility with Standard Parameter's Lighting	The lighting conditions in degrees Kelvin for a perception of comfort for the users of an environment are in the range of 4000 to 6500 Kelvin.
Zheliazkov (2023)	2023	Research article	System of Circadian Lighting Based on Determination of Human Thermal Comfort Level	Perceptions of CT are different for each person. The study shows different values according to the thermal conditions of the environment, making visible a relationship between the quality of the environment, CT, and the emotional state of people.
Chen (2022)	2022	Research article	How color temperature and illuminance affect psychology, physiology, and productivity.	The subjects preferred 4200 K color temperature and 500 lux levels. Energy-saving, productivity, psychology, and circadian rhythm were the key points for controlling lighting in the three proposed strategies.
Babu (2022)	2022	Research article	Impact of window view classrooms on architecture students' performance	The results show that the classrooms holding a view of nature or landscape show significant performance in attention and cognitive skills. Hence, designers must work together to give students access to natural window views.
Márquez (2022)	2022	Research article	Improvements in lighting conditions in standard classrooms in new schools	Designs with greater access to natural light achieve a reduction in energy expenditure of more than 40%, favoring efficiency and the limited use of artificial light.
Zhang (2022)	2022	Research article	The emotional state in waiting rooms is associated with white and colored light.	The results showed that colored light caused a 20% reduction in joy for men; conversely, the level for fear increased by 20%. The emotional state in interior environments can be more easily expressed with dimensional models of data processing with final values in discrete models.
Syarif (2022)	2022	Research article	Experimental research on daylight performance in higher education learning space.	The light levels vary in each location, such as next to the blackboard between 284 to 325 lux, next to the window between 3100 to 3340 lux, and with the curtain 50% open the light barely reaches the middle of the room.
Natalia (2022)	2022	Research article	Lighting and opening as a strategy in primary school classrooms in Jakarta.	The lighting standard for classrooms established by the National Standardization Agency is 350 lux and is close to the 60% value set for an opening area in learning spaces.

Table 1. (*Continued*).

Author	Year	Type of Study or document	Problem	Explanation/Solution/Conclusion
Llinares (2021)	2021	Research article	Should lighting be the same for attention tasks as for memory tasks?	Lighting design conditions that support value-based cognitive processes show the association between lighting and student performance.
Ahmed (2021)	2021	Research article	Effects of Design Openings Elements on Energy Efficiency of Educational Buildings	Energy consumption decreases to 45% considering the new model compared to the old one that used over 60% for lighting. setting favorable values for windows in classrooms at 20%, for administrative management at 25%, learning spaces at 25%, and for students and hallways at 65%.
Lekan-Kehinde (2021)	2021	Review article	Impact of lighting on children's learning Environment	The study of lighting in learning spaces shows that there is an association between lighting conditions, such as blue-enriched light, and learning, cognitive aspects, concentration, memory, processing, and speed; an effective choice of the lighting system favors the emotional state of students in learning and cognitive skills.
Sun (2021)	2021	Thesis	Self-sufficient lighting systems and academic improvement: Innovation in learning spaces, designs, and implementations.	Students in a context-based lighting environment improved significantly more in both language and mathematics than those in a standard lighting environment. Through MANOVA, no differences in gender were visible, but through *t*-tests, a significant effect was found in women. The complexity of the study is high.
Králiková (2021)	2021	Research article	Study on how employee comfort and health are affected by workspace conditions: The lighting system of workspaces, design, and optimization.	The cycle between sleep and wakefulness is influenced by the harmony between daylight and the circadian rhythm, and this environment affects people's performance and health. Configure the parameters of the lighting systems according to the time conditions, the work performed, and the user's own requirements that determine a perception of space and visual comfort.
Won (2020)	2020	Research article	Effect of LED Lighting Illuminance and Correlated Color Temperature on Working Memory	As a result, working memory performance was the best in the 1000-lux, 5000-Kelvin condition mean.
Almarez (2020)	2020	Research article	Evaluation of Compliance with the Lighting	It was observed that the amount of daylight greatly influences the light intensity within the workspace and that the lighting solutions installed were not able to supplement daylight to achieve the prescribed level of illuminance.
Oribo (2020)	2020	Research Article	The Effects of Artificial Classroom Lighting on Student's Academic Performance	In general, well-designed and quality artificial classroom lighting will improve secondary school students' academic performance. A good artificial classroom illumination ranges between 300 lux and 500 lux.
Liu (2020)	2020	Research Article	Influence of Classroom Illumination Environment on the Efficiency of Foreign Language Learning	Determination of Salivary Amylase Activity and Subjective Evaluation Questionnaire on "Concentration" and "Association". Japanese vocabulary association was largely influenced by illuminance but only slightly influenced by color temperature. The illuminating condition of high illuminance (650 lux) and low color temperature (4000 Kelvin) was the most ideal classroom illuminating condition for Japanese language learning efficiency.
Yang (2020)	2020	Research article	Effects of Correlated Colour Temperature of LED Light on Visual Sensation, Perception, and Cognitive Performance in a Classroom Lighting Environment	The CCT is proportional to the sensation of brightness, the educational lighting comfort is at 4000 K, and the perceptual properties, satisfaction, and acceptance are maintained from 3000 Kelvin to 5700 Kelvin. The memory test level is affected by the CCT and illuminance only in men. Women were sensitive to the sensation of glare with a low working memory test. An optimal CCT is more beneficial than higher illuminance in moderately ambient indoor lighting conditions.

Table 1. (*Continued*).

Author	Year	Type of Study or document	Problem	Explanation/Solution/Conclusion
Baeza (2020)	2020	Review article	Towards a Sustainable Indoor Lighting Design: Effects of Artificial Light on the Emotional State of Adolescents in the Classroom	The creation of new LED luminaires for interior lighting, including in educational centers, where the intensity of blue light can be increased without any specific legislation for its control, makes regulatory development imperative due to the possible repercussions on adolescents with unknown and unpredictable consequences.
Won (2020)	2020	Research article	The Influence of LED Lighting on Attention and Long-Term Memory	Attention is the best at 1000 lux, a relatively bright light condition, and long-term memory is the best at 400 lux. Long-term memory was measured by using the WFC task.
Hansen (2018)	2018	Research article	The Impact of Dynamic Lighting in Classrooms. A Review on Methods	The learning environments, to a broader extent, should be studied and designed holistically through a mixed-methods approach.

In the analysis of the information, we can identify articles that present similar evidence, among which the following three representative cases stand out shown in **Table 2**:

Table 2. Representative cases considering the diversity in related research.

Case and Year	Title	Participants, mean age & Diagnose status.	Illuminance levels, devices & q	Conditions Experiment Environment	Measurement condition	Memory Measurement	Statistical Analysis Method
I 2020	The Influence of LED Lighting on Attention and Long-Term Memory	5 man + 13 women = 18 college students. 23.3 years old. No cognitive impairment	300 lux, 400 lux, 500 lux, and 1000 lux. 12 lamps of 9 cm in diameter and contained 5 small LED bulbs	PMV conditions of ASHRA Standard	Attention: 10 symbols corresponding to 10 keys. Choose the correct selection to move to the next option	Long-Term Memory WCF Tasks. 1e nonsense syllable task was to learn 20 items per one illuminance condition	repeated measure ANOVA through SPSS 20.0. Post hoc analysis was performed using the LSD method. Significance $p < 0.05$.
II 2020	The Influence of Classroom Illumination Environment on the Efficiency of Foreign Language Learning (F.L.)	50 2nd-year university students (five groups, 10 students per group). Not specific years old. N2 certificate as F. L.	Illuminance of 650 lux (325 lux) and a high (low) color temperature of 5000 Kelvin (4000 Kelvin). Not a specific device.	The four different combinations of Lux and Kelvin. were all within the range of Kruithof ‘s pleasing zone	Learning efficiency: Several associated Japanese words of every group in different illumination environments. Showed in bar chart & box plot	Stress status: The salivary amylase activity value detected stress status under different illumination environments	T-test with Significance $p < 0.05$. J. Vocabulary mind-map, salivary amylase activity, questionnaire & evaluation.

Table 2. (*Continued*).

Case and Year	Title	Participants, mean age & Diagnose status.	Illuminance levels, devices & q	Conditions Experiment Environment	Measurement condition	Memory Measurement	Statistical Analysis Method
III 2022	Effect of Color Temperature and Illuminance on Psychology, Physiology, and Productivity: An Experimental Study	67 subjects in Taiwan. 34 males and 33 females. They didn't have any major organ diseases or physio-logical abnormalities and corrected visual acuity was between 1.0 and 1.2	Illumi-nance < 200 lux, 200~500, and > 500 lux, CCT 3000 Kelvin, 4000 Kelvin and 5500 Kelvin. Smart lighting system with a controllable light-emitting diode (LED)	The WELL standards. Scenarios were 3000 Kelvin-280 lux-120 EML, 4000 Kelvin-210 lux-120 EML, 5500 Kelvin-175 lux-145 EML, 3000 Kelvin-590 lux-250 EML, 4000 Kelvin-420 lux-250 EML, 5500 Kelvin-350 lux-300 EML. 5 min to adapt to light conditions. 5,10,15 min tests time.	Subjective Psychological Evaluation: questionnaire with semantic differential technique (SDT) & KSS. Work Productivity Evaluation: work performance series (ASL) and the differential attention test (DAKT). Physiological Changes Evaluation: EEG and ECG and the heart rate in bmp.	Not specific. Another condition for measurement of the influence of the light on the circadian rhythm for the EML is the melatonin in saliva.	*T*-test with Significance $p < 0.05$, $p < 0.01$ and $p < 0.001$. The graphic result in box plot and lines.

3. Results

Summarizing shows the representative highlight results for each case, respectively, as shown in **Figures 8–10**.

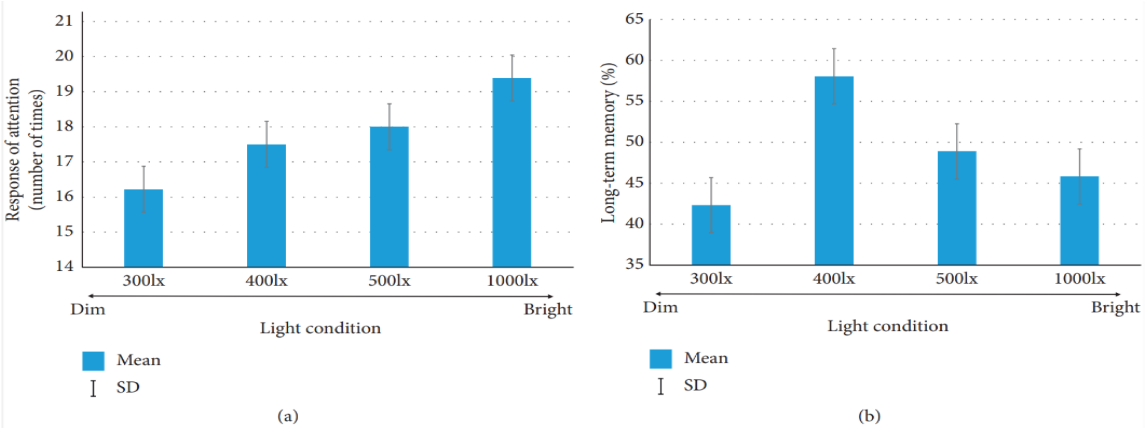

Figure 8. Difference between **(a)** attention; **(b)** long-term memory according to illuminance of LED lighting (Won, 2020).

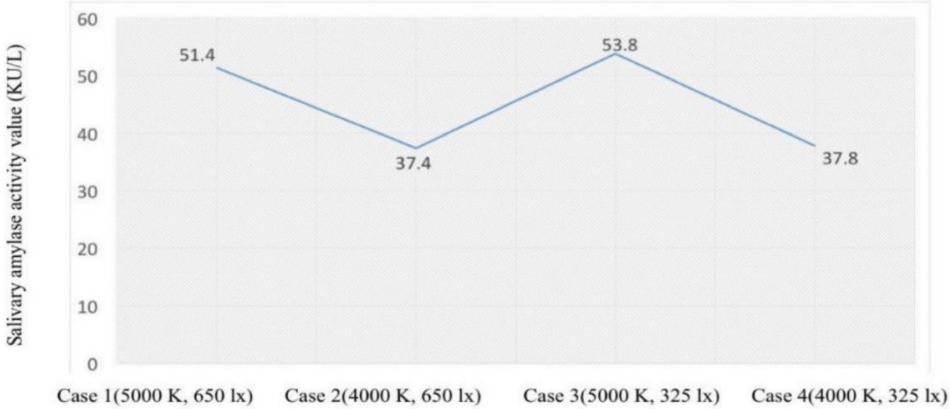

Figure 9. Averages of salivary amylase activity values in different illumination environments (Liu, 2020).

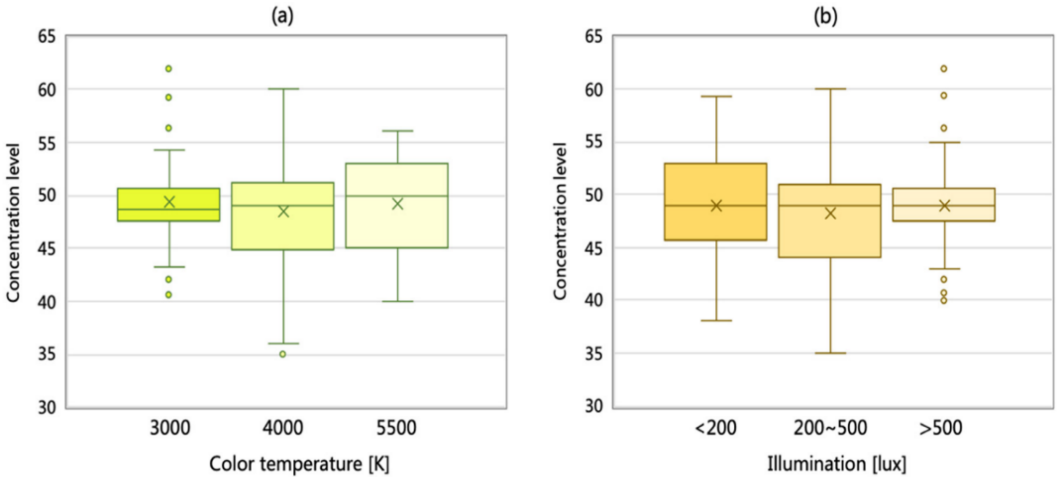

Figure 10. Concentration level and average heart rate of different CCTs and illumination: **(a)** The difference in brain waves under different CCTs; **(b)** The difference in brain waves under different illumination (Chen, 2022).

Analyzing the information, the tendency for articles more closely related to the topic is shown in **Figure 11**.

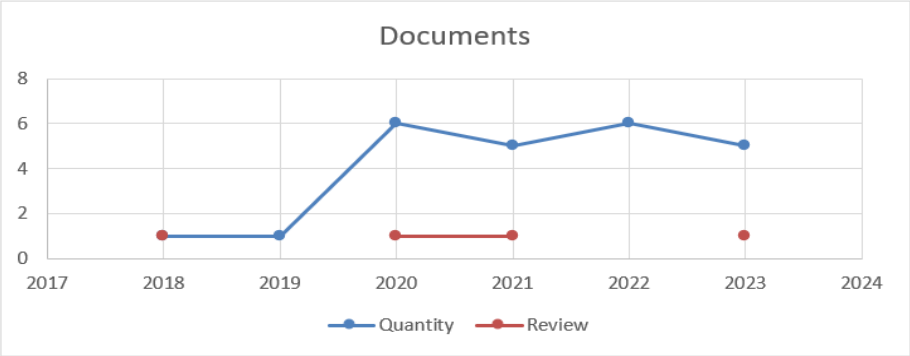

Figure 11. Documents related to the main topic.

After processing the Kelvin ranges of better conditions, we can show **Figure 12**.

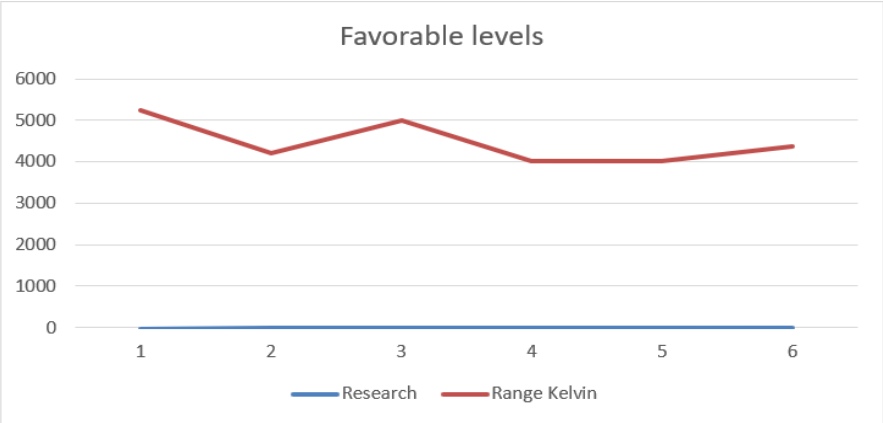

Figure 12. Kelvin average favorable levels.

After processing the Lux ranges of better conditions, we can show **Figure 13**.

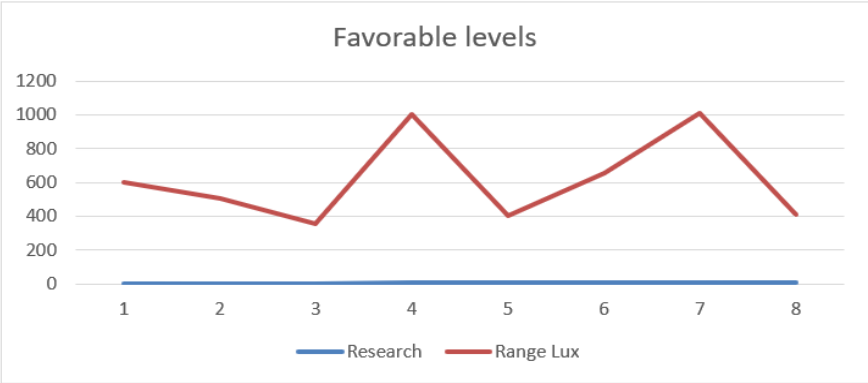

Figure 13. Lux average favorable levels.

This study shows a proposal for developing experimental research:

Design classroom. It involves considering all aspects of learning spaces, infrastructure, and real estate in the design of their shapes, materials, and colors; natural and artificial lighting; as well as audiovisual equipment.

Design instruments. In the literature review, we identified various instruments used to determine the relationship between lighting conditions and the student's learning level, among which we have questionnaires, typical tests and tests designed by the researchers, ECG, EGG, and salivary amylase activity, among others.

Fine-tuning light. Studies show that we must be extremely careful in setting test values to take the correct measures and identify the range and favorable value for each emotional state of the student.

Testing. Measurements must be taken under conditions that allow identifying the lighting parameter(s) that influence the learning level without altering the test scenarios and obtaining correct results.

Data collection. Measurements must be taken with instruments such as a lux meter and spectrometer, as well as with medical instruments such as an electrocardiograph, electroencephalograph, pulse meter, pulse oximeter, respirometer, and test kit to measure melatonin in saliva, salivary amylase activity, and questionnaires, and carefully recorded and organized according to your process.

Processing. The data processing responds to the researcher's design, and among them, we have statistics such as the "student's *t*-test", "chi-square," and "Cronbach's alpha," among others.

Results. The authors may consider giving greater emphasis to the results, and they should be clear and explicit; graphical and numerical; and they should include relevant information.

Conclusions. They are the contribution of the researcher; they must be clear, and concise, show deductions and relationships between important findings and variables of the results or other contents of the research, and some of them must be supported by quantitative data for greater precision.

4. Discussion

The starting point of the research is quality education and sustainability in education, which has a direct relationship with sustainability in energy-oriented lighting, seeking energy savings, and reducing the carbon footprint.

The trend in power generation is towards green energy, although the payback time is long term and generates uncertainties, it presents sustainable benefits over time, reducing the consumption of fossil fuels (Emeida, 2022).

A fundamental factor to consider is daylight, which, considering the circadian rhythm, influences people's health and should be considered in studies by designers of human-centered buildings (Nagare, 2021).

The use of applications facilitates the visibility of processes and results. In the lighting conditions in learning spaces and their influence on student performance, lighting and architectural solutions design software for lighting system controls are very useful, saving energy and contributing to the reduction of CO_2 (Králiková, 2022).

In research, the clarity of the objectives is essential, and based on them, the instruments and research scenarios are designed. Among the instruments necessary to measure the lighting conditions in the classroom are the lux meter and the spectrometer. We also must measure the effects. creative options such as measuring the salivary amylase activity and the melatonin in saliva or other instruments such as the electrocardiograph, electroencephalograph, pulse meter, pulse oximeter, and respirometer. Another option is the use of questionnaires specially designed for each test, showing related health and emotional conditions (Amira, 2020).

LED lighting systems that are adjustable in light intensity and color temperature are important elements in a technological solution that allows an optimal level of lux and degrees Kelvin for each type of activity to be carried out (Fu, 2023).

5. Conclusion

- Research on the influence of lighting conditions on the performance of students or workers has increased since 2020.
- The circadian rhythm is related to daylight, which influences student health, and visual health affects learning conditions.
- The design of buildings and classrooms should use daylight and consider optical phenomena, and the classroom lighting parameters should be fine-tuned according to the courses and activities.
- The student's sensorial perception is affected by the light in learning spaces, and the physical and emotional state of the student influences the learning process.
- The range of favorable lenses for learning and productivity is CCT of 4000 k to 5250 k and illumination of 350 lux to 1000 lux.
- A holistic investigation is important to achieve a comprehensive solution, considering that multiple variables are involved in the learning process.
- There are various methods to measure the change in the student's physiological and psychological conditions, some with invasive and non-invasive tests such as ECG, EGG, salivary amylase activity, heart rate, WFC task, questionnaire with SDT and KSS, ASL, and DAKT test.

Conflict of interest: The authors declare no conflict of interest.

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