Impact of LED lighting in the school international

Impact of LED Lighting on Different Age Groups

A. Early childhood (Age 3-6)

- Activities: Play-Based Learning, art, storytelling, naps
- Lighting Needs:
  - Warm white LED (2700K, 3000k): comforting and calming
  - High CRI (>90): for accurate color perception in arts and visuals
  - Soft indirect lighting: prevents overstimulation
  - Dimmable zones: for quiet time or nap areas
- Key Effects:
  - Reduced anxiety and increased emotional stability
  - Supports healthy circadian rhythms and nap routines

B. Primary School (Age 6-12)

- Activities: Reading, math, science, crafts, group learning
- Lighting Needs:
  - Cool white LED (3500K- 4000K): increases focus and alertness
  - 500-700 LUX on desks
  - Low glare (UGR< 19): Prevents visual fatigue
  - Daylight integration: balances natural and artificial lighting
- Key Effects:
  - Improves reading speed and comprehension
  - Increases attention span and academic engagement
  - Reduces eye strain during long learning sessions

C. Middle and High School (Ages 13-18)

- Activities: Exams, Lab work, computer use, presentations
- Lighting Needs:
  - Neutral to cool white(4000k-5000k): supports concentration
  - Variable lighting scenes: exam mode (bright/cool), discussion mode (medium/neutral), break mode (dim/warm)
  - Flicker-free LED drivers: for screen-heavy environments
  - Glare control and anti-reflective surfaces
- Key Effects:
  - Enhances cognitive performance during exams
  - Improves mood and mental alertness
  - Supports digital eye health

3. Effect of LED Lighting Based on Activities

Activity	Ideal LED Features	Recommended Lux	Notes
Classroom Learning	3500–5000K, high CRI, low glare	500–700 lux	Dimming for screen work
Art & Design Rooms	3000–4000K, CRI ≥ 90, directional spots	750–1000 lux	Color accuracy critical
Libraries	3500K, even illumination, quiet zones	300–500 lux	Visual comfort prioritized
Science Labs	4000–5000K, strong task lighting	750 lux	High visibility needed
Sports Halls	5000K, wide distribution, shatterproof	300–500 lux	Anti-glare essential
Corridors	3000K, motion sensors	100–200 lux	Energy saving critical
Restrooms	3000K–3500K, IP-rated fixtures	200–300 lux	Hygiene and visibility
Outdoor Playgrounds	4000–5000K, durable LED floodlights	50–200 lux	Safety and visibility after sunset

4. Circadian Lighting & School Timing

Led lighting can mimic daylight cycles, supporting biological clocks:

- **Morning (8–11 AM)**: Bright, cool light (4500–5000K) enhances alertness.
- **Afternoon (1–3 PM)**: Neutral light (3500–4000K) prevents fatigue.
- **Late classes**: Warmer dimmed lighting to reduce overstimulation.

Effects of LED Lighting Fixtures in International Schools: A Comprehensive Review

Introduction

LED lighting in educational facilities directly impacts students' biological, cognitive, and emotional development. Key parameters—illuminance (lux), color temperature (Kelvin/K), color rendering index (CRI), and glare—play distinct roles for different age groups and activities within the learning environment.

1. **Biological and Developmental Considerations by Age**

Early Childhood (Preschool to Early Elementary)

- **Preferred Color Temperature:** Warm (2,700K–3,000K). Fosters a sense of comfort, creativity, and security—suited to the developmental need for calm and nurturing environments.
- **Lux Levels:** 300–350 lux for general activity. Dim, warm lighting supports rest and imaginative play but should be bright enough to aid visual development and task engagement.
- **Biological Impact:** Young children are more sensitive to glare due to developing visual systems, and excessive brightness can be overstimulating. Proper lighting supports circadian rhythm alignment and early sleep/wake development

Late Elementary to Middle School (Ages 8–12)

- **Color Temperature**: Neutral-to-cool white (3,500K–4,100K). Enhances focus and concentration as children develop more structured cognitive processing.
- **Lux Levels**: 350–500 lux for schoolwork. Higher light levels help maintain alertness and minimize visual fatigue during reading/writing tasks.
- **Biological Impact**: Children in this group benefit from increased blue-rich light in the morning to stimulate alertness, matching the biology of shifting sleep cycles and increasing academic rigor

High School and Adolescents (Ages 13–18)

- **Color Temperature**: Cool (5,000K–6,500K). Mimics daylight, optimal for alertness, faster cognitive processing, and reduced drowsiness.
- **Lux Levels**: Up to 750 lux for detailed tasks, 500 lux for general classroom activities, and higher for laboratories or art rooms.
- **Biological Impact**: Adolescents' melatonin secretion phase shifts later, causing natural “sleep in.” Bright, blue-rich lighting during the day helps shift circadian rhythms earlier and boosts academic performance and alertness

College and Adult Learners

- **Color Temperature**: Daylight simulation (5,000K–6,500K), especially for intense study sessions.
- **Lux Levels**: 500–750 lux or higher for technical or laboratory work.
- **Biological Impact**: Supports mental endurance, critical thinking, and reduces fatigue over long hours

2. Lighting Parameters for School Activities

Activity Type	Typical Lux Level	Color Temp. (Kelvin)	CRI	Glare	Biological Relevance
General Classroom	300–500	3,500–5,000	>80	Low	Aids focus, minimizes fatigue, supports circadian rhythm
Reading, Desk Work	500–750	4,000–5,000	>80	Very Low	Enhances cognitive performance, reduces eye strain
Detailed Work (Labs)	750–1000	5,000–6,500	>90	Very Low	Maximizes alertness, accuracy, and color perception
Rest Areas/Quiet Time	100–300	2,700–3,000	>80	Low	Supports relaxation, reduces hyperactivity in young or special-needs students
Computer Use	300–500	4,000–6,000	>80	Minimal	Reduces glare off monitors, supports comfort for prolonged screen use

- **Lux**: Brightness that matches task and age; underlit spaces impair performance, while overly bright may cause glare and eye strain.
- **Color Temperature**: Matches the biological need for alertness or relaxation.
- **CRI (Color Rendering Index)**: At least 80 for classrooms, 90+ for science/art, to maintain accurate color perception and reduce visual fatigue.
- **Glare**: Minimized by using diffused light, indirect fixtures, and matte surfaces. Prevents visual discomfort and distraction, especially crucial for younger children and those with sensory sensitivities

3. Specific Biological Mechanisms

- **Circadian Rhythm Regulation**: Higher blue-content (cooler) light in the morning helps suppress melatonin, increasing alertness and harmonizing body clocks to the learning schedule. Warmer light in afternoon helps prepare for transition to rest and home.
- **Cognitive Function**: Research demonstrates increased reading speed, reduced errors, and higher attention levels under higher color temperature and recommended brightness. For example, schools with tunable LEDs reported a 35% increase in reading speed and a 45% reduction in errors.
- **Hormonal Effects**: Exposure to optimal light intensity and spectrum affects secretion of cortisol (stress regulation) and melatonin (sleep), which directly modulate attention span, memory, and mood.
- **Visual Development**: For younger ages, adequate brightness and high CRI support visual system maturation and reduce risk of myopia and other visual strain disorders.

4.**Special Considerations**

- **Flicker-Free LEDs**: Essential to avoid headaches, eyestrain, and exacerbation of hyperactivity or neurological conditions (e.g., autism spectrum). Flicker-free technology is recommended for all age groups, especially primary and special education classrooms.
- **Glare Management**: Use fixtures with diffusers or indirect designs, especially near digital displays or in rooms with matte surfaces. Glare can affect learning performance, particularly in students with vision impairment or sensory sensitivities.
- **Dynamic/Tunable Lighting**: Systems that allow teachers to adjust both brightness and color temperature to suit time of day and activity have been shown to boost academic engagement, enhance mood, and reduce off-task behaviors

References to Core Biological Evidence

- **Task Performance**: Higher CCT, especially 5,000–6,500K, improves cognitive task switching in both preschool and older students, attributed to increased blue light stimulating melanopsin-sensitive cells in the retina, boosting alertness.
- **Behavior Management**: Tunable LED lighting has been linked with a decrease in hyperactivity for children with learning challenges when using calm (low-lux, warm) settings, and increases engagement during high-focus activities with bright, cool-white settings.
- **Visual Health**: High CRI LEDs (>80, ideally >90) prevent color inaccuracies and eye strain, supporting accurate information processing necessary for all age-appropriate tasks.
- **Mitigating Glare Impact**: Unified Glare Rating (UGR) standards recommend values below 19 for classrooms to prevent disability and discomfort glare

Conclusion

Optimal LED lighting in schools must be tailored to age group, activity, and biological requirements:

- **Warm, low-glare, moderate-brightness light** for younger children and calming activities.
- **Cooler, bright, high-CRI light** for study, labs, and detailed tasks in older age groups.
- **Dynamic and flicker-free systems** ensure health, comfort, and academic performance across all ages, supporting students' biological rhythms and cognitive development.
- **Attention to glare** and light distribution further maximizes inclusivity, particularly for students with visual or sensory differences

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Four lighting scenarios included (Fig. 1): Standard, Smart Board, Fresh, and Relax. For Standard: Ceiling luminaries were at 300lx, 3500k, Board Luminaries at 500lx, 3000k, and Wall Washer was off; for Smart Board, ceiling luminaries were at 300lx, 3500k, Board Luminaries at 300lx, 3000k and Wall Washer at 300lx, 4000k; for the Fresh scenario, ceiling

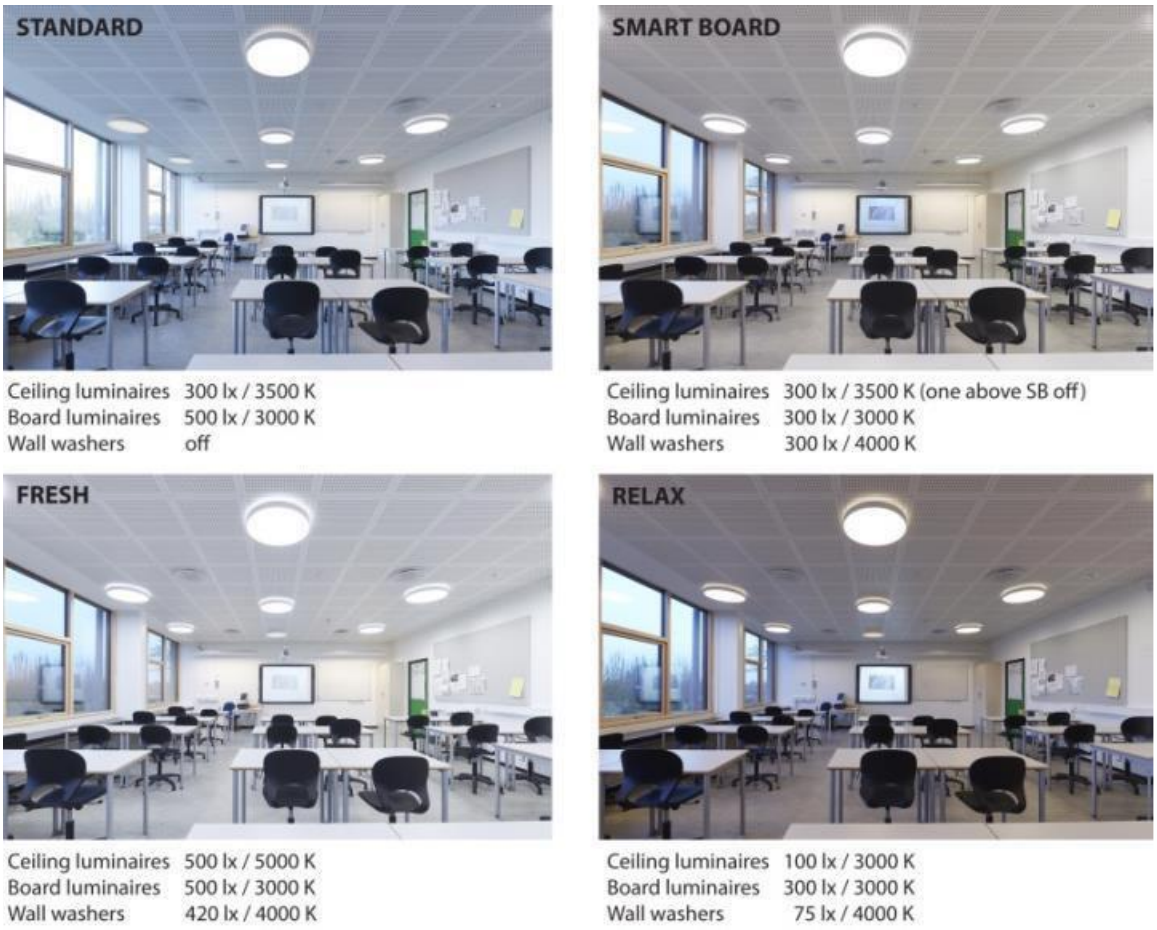


Figure 1.The illumination level and correlated color temperatures of different luminary

luminaries were at 500lx, 5000K, board luminaries at 500lx, 3000K, and the wall washer at 420lx, 4000K; while for the Relax scenario, ceiling luminaries were at 100lx, 3000K, board luminaries at 300lx, 3000K and the wall washer at 75lx, 4000K.

Experiment Procedure. In this study, all participants were randomly allocated to all four conditions of 300 lx, 400 lx, 500 lx, and 1,000 lx through a repetitive measurement experiment design. Prior to each learning task per condition, participants underwent the two-minute dark and light adaptation periods, respectively. Over the next 10 minutes, participants learned about 20 nonsense syllables. After 10 minutes of the learning, the participants soon completed the working memory task. In the attention task, where performance was measured using a cognitive response measuring device, the number of correctly responded symbols in one minute was counted for use as a dependent variable. Subsequently, the participants returned to the experimental laboratory exactly 24 hours later and performed a long-term memory task of 20 items based on previous learning. The long-term memory was measured using the WFC task, and the proportion of the correctly recognized items out of the 20 items was obtained for use as a dependent variable. The specific experimental procedure is shown in Figure 5.

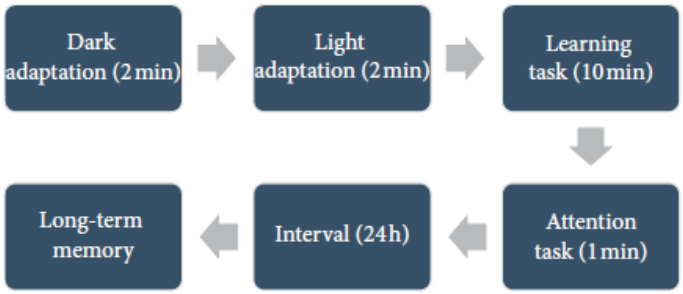


Figure 5: Experimental procedure.

Table 1: Descriptive statistics of attention and long-term memory according to illuminance of LED lighting.

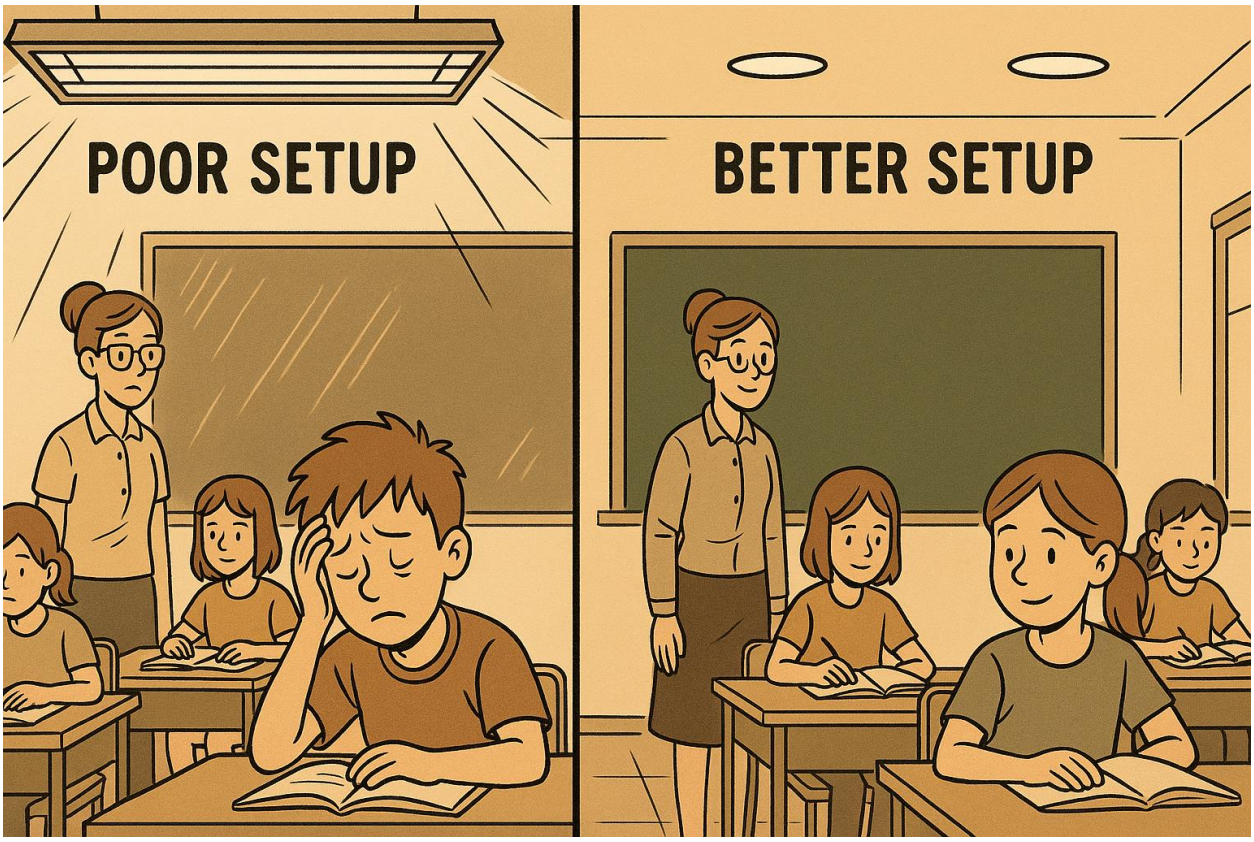
Illuminance levels (lux) (lx)	Attention (a number of times)		Long-term memory (%)		N
	Mean	SD	Mean	SD	
300	16.22	3.78	43.33	19.10	18
400	17.50	5.54	58.06	22.57	18
500	18.00	5.18	48.89	20.33	18
1000	19.39	5.42	45.83	23.53	18

Table 2: ANOVA results of attention and long-term memory according to illuminance of LED lighting.

	DF	SS	MS	F	p
Attention	3	92.56	30.85	3.39	0.025*
Long-term memory	3	2234.72	744.91	3.21	0.031*

*$p < 0.05$.

illuminance of LED lighting was made through a repeated measure ANOVA through SPSS 20.0 (SPSS Inc., Chicago, IL, USA). Post hoc analysis was performed using the LSD method. Significance was de6ned as $p < 0.05$.


POOR SETUP
BETTER SETUP

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