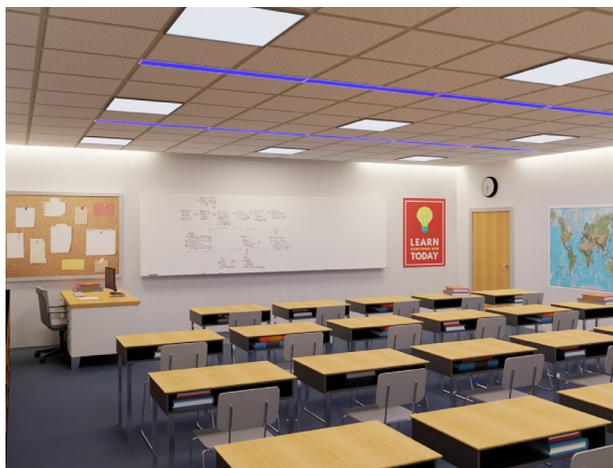


# Lighting for Schools



The circadian rhythms and sleep-wake cycles of young children are relatively stable, but gradually shift toward a preference for late-morning wake times and late-onset sleep times [124, 125]. Changes to sleep-wake cycles and circadian phase begin around 5-7 years of age, with greater delays around 12-14 years [126-129].

Despite adolescent inclination for “late to bed and late to rise,” highly structured school schedules require early start times, which often leads to reduced sleep duration among students. Furthermore, by keeping children in classrooms all morning, they can receive inadequate exposure to morning light for stimulating the circadian system and entrainment to the 24-hour solar day, especially during

the dark winter months [130]. In late spring, if adolescents spend more time outdoors after school, their circadian rhythms may be delayed by evening daylight exposure [131]. Adolescents’ sleep can be even further compromised by nighttime exposure to self-luminous electronic devices (e.g., cellphones, tablets, laptops, etc.), which provide an alerting stimulus and suppress melatonin secretion [131].

In addition to circadian phase delay, evidence has also emerged suggesting that the adolescent circadian period is longer, sleep pressure accumulates more slowly, and the sensitivity to evening light by the circadian system is greater than in adults, especially among those with delayed sleep phase disorder (DSPD) [135, 136]. In fact, a recent LRC study showed that adolescents (ages 15-17 years) are more sensitive to evening light from self-luminous devices than those in their twenties [132]. Both of these factors delay the timing of the adolescent circadian clock, thereby contributing to later bed and rise times.

## Pre-teens and adolescents

Pre-teens (K-5th grade)	
Time	CS
Wake - 3:00 PM	0.3
3:00 PM - 4:00 PM	0.3 → 0.1
4:00 PM - Bed	0.1

Teens (6th-12th grade)	
Time	CS
Wake - 12:00 PM	0.4
12:00 PM - 1:00 PM	0.4 → 0.3
1:00 PM - 3:00 PM	0.3
3:00 PM - 4:00 PM	0.3 → 0.1
4:00 PM - Bed	0.1

Pubertal development is associated with accumulating delay in the preferred timing of sleep and waking that contributes to significant reductions in total sleep time during adolescence [129, 135-143]. A report by the National Sleep Foundation states that, even though adolescents require as much sleep as pre-adolescents (about 8.5 to 9.25 hours per night), they tend to fall asleep later (about 11:00 PM), averaging only 7.75 hours of sleep per night at age 13. Total sleep time decreases even further to around 7 hours per night by the time this population reaches the age of 19 [144].

DSPD is characterized by the American Academy of Sleep Medicine as a circadian sleep-wake disorder involving sleep onset that occurs significantly later than desired bedtimes and societal norms [149]. DSPD is common among adolescents [150-152] and increases their susceptibility to chronic sleep restriction and associated detrimental outcomes [153].

Individuals with DSPD have difficulty falling asleep at conventional bedtimes. Patients are diagnosed with DSPD if these symptoms cause distress and impairment and if they persist for at least 3 months. More than 8% of adolescents may have DSPD [153-155], which increases their risk for poor scholastic performance and behavioral problems.

A lighting intervention may help shift the timing of sleep in adolescents. Deliver light beginning in the early to mid-morning (for example, after 8:30-9:00 AM), extend throughout the school day, and reduce evening light exposures (e.g., wearing orange-tinted glasses, control use of self-luminous devices). Successful light therapy with adolescents will likely involve both school administrators and family members.

## Special needs students

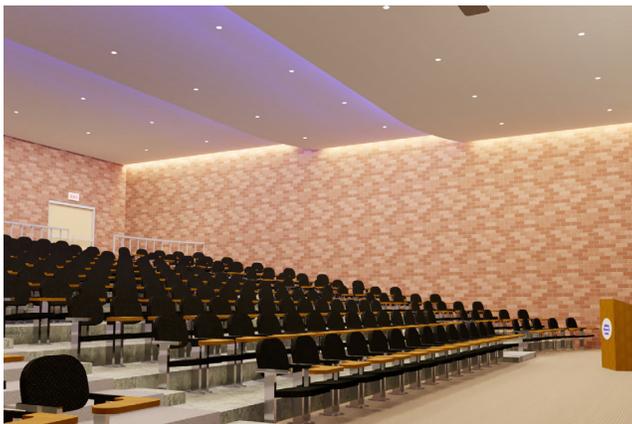


Special education classrooms provide specialized learning environments for students with learning difficulties or physical disabilities [176]. Many special education students are especially sensitive to stimuli in the lighted environment, and are susceptible to overstimulation from bright and/or flickering light [177]. This can lead to repetitive behavior and agitation, tics, and epileptic episodes [178]. Older classrooms are commonly lighted with 2x4 fluorescent troffers with a typical flicker frequency of 60 Hz; the resulting stroboscopic effect is increasingly noticeable with age of fixture [179]. A few options to mitigate the effects of flicker include integration of daylight with electric lighting, introduction of constant-current

Special needs (K-12th grade)	
Time	CS
Wake - 2:00 PM	0.3
2:00 PM - 3:00 PM	0.3 → 0.2
1:00 PM - 3:00 PM	0.2
3:00 PM - 4:00 PM	0.3 → 0.1
4:00 PM - Bed	0.1

LEDs, and ensuring luminaires are compatible with their dimming system. The use of blue light is a viable solution for creating a classroom environment that reduces light stimulus while still ensuring that students' circadian needs are met. In addition to a programmed light schedule, manual override options should be available for teachers.

## College students



The adolescent pattern of late sleep onset and late waking continues through students' college years [165-169]. One study indicated that 73% of college students reported at least occasional sleep problems [166], while another showed that more than 48% of students suffer from sleep debt. Student stress, social habits, and educational demands contribute to problems sleeping. One large-scale study of college students found that about 60% report poor sleep quality [170], and another study reported college students' difficulty falling asleep (15%), frequent nighttime waking (26%), and fulfillment of the diagnostic criteria for insomnia (8%) [171].

College- Early riser	
Time	CS
Wake - 5:00 PM	0.3
5:00 PM - 6:00 PM	0.3 → 0.2
6:00 PM - 8:00 PM	0.2
8:00 PM - 9:00 PM	0.2 → 0.1
9:00 PM - Bed	0.1

The tendency to delay bedtimes and extend rise times increases the risk for serious consequences of sleep debt [149, 170]. Sleep quality is closely linked with mental and physical health and well-being, thus intervention programs aimed to improve sleep in this population are recommended [165, 168-170].

College- Night owl	
Time	CS
Wake - 5:00 PM	0.3
5:00 PM - 6:00 PM	0.3 → 0.2
6:00 PM - 10:00 PM	0.2
10:00 PM - 11:00 PM	0.2 → 0.1
11:00 PM - Bed	0.1

A lighting intervention may help shift the timing of sleep in college students. Deliver light upon waking, extend throughout the day, and reduce evening light exposures (e.g., wearing orange-tinted glasses during evening use of self-luminous devices). Light therapy also has the potential to improve mood and depression with college students. Successful lighting interventions in this population would best involve educational facilities managers (e.g., lecture theater, classroom, and dormitory lighting) and the active participation of the students themselves.

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