Tunable Lighting Use in a Special Needs Preschool

Shining Stars Preschool

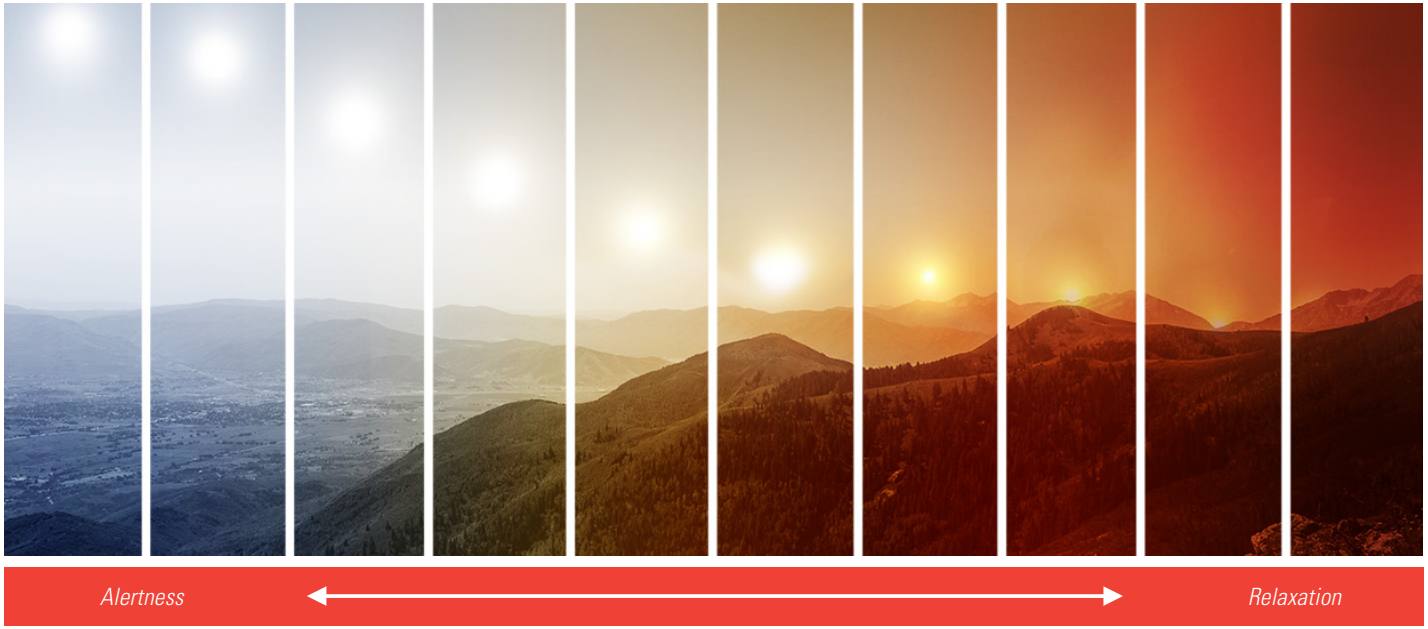
DEKKER
PERICH
SABATINI

ARCHITECTURE
IN PROGRESS

Abstract

Classroom lighting has evolved in recent decades to improve energy efficiency and provide users more control over the amount and location of lighting, but the newer, less common technology of tunable white lighting poses new opportunities and questions. Tunable white light enables users to adjust lighting color temperature using a simple slider control or complex lighting control system. This tuning has an immediate impact on how cool, warm, or neutral the color of the light is within a space, which studies indicate can impact occupants' mood, behavior, and productivity.

In an outdoor environment, it is easy to see how natural light shifts over the course of a day from cool blue light in the morning to a whiter light during the middle of the day and a warmer, redder light toward evening. Our circadian system follows the natural progression of light and dark throughout the 24 hour day. During the day melatonin production stops, our body temperature rises, and we become more alert and productive and physically stronger. In recent years this has become more obvious to non-scientists, as the use of digital screens that give off blue light has increased, and their cool, blue light can make it more difficult to fall asleep at night.



CIRCADIAN LIGHT

The study of circadian lighting or tunable white lighting on humans is still in its infancy. Some 24-hour environments like nursing homes, prisons, and behavioral health facilities are experimenting with lighting systems controlled by timers to mimic the daily cycle of natural light. Some schools have started using this knowledge of color temperature in a different way. Rather than mimicking the daily cycle, lighting color temperature can be adjusted based on tasks or the needs of specific students. Teachers can select a cooler light temperature for concentration tasks, or a warmer light temperature for storytime to ease students back into academic work after playing outside, while using a more neutral temperature for most of the school day. The potential impact of lighting temperature on productivity might be easier to quantify using metrics such as test scores for older students. However, tunable lighting may provide more qualitative benefits for preschoolers and students with special needs, by allowing teachers to fine-tune lighting for their individual class's needs.

A tunable white lighting system was installed in over 30 classrooms/learning spaces at a newly constructed preschool for students with special needs, based on the school's goals and evaluation of multiple lighting products. During the first semester of occupancy, teachers were given an educational presentation about tunable lighting, and teachers logged lighting adjustments made over a 2-week period to provide information about how the lighting system was being used. This effort was intended to help make sure the preschool gets the most benefit out of their new lighting system, to help inform future design/purchasing decisions by the school district, architect, and electrical engineer, and to share information with other schools considering tunable white lighting systems.

About Shining Stars Preschool

Shining Stars Preschool (SSP) is an inclusive preschool facility for 3-4-year-old children owned and operated by Rio Rancho Public Schools (RRPS) in Rio Rancho, New Mexico. SSP's diverse population includes students with developmental disabilities, autism spectrum disorders, visual impairments, speech delays, behavioral differences, and other special needs.

Prior to the construction of the new campus, SSP was housed in an old elementary school that consisted mainly of modular and portable buildings with overhead fluorescent lighting. Control of lighting levels and light color/temperature was identified early in design as a major source of frustration with Shining Stars' existing learning environments. In many of the existing classrooms, overhead fluorescent lights had been covered with fabric, were left completely off, and/or were replaced by or supplemented with residential-style lamps with low, warm light. A lighting analysis of the existing facility was conducted by the electrical engineer to document existing lighting controls, light levels, and modifications to building lighting.

HARSH LIGHTING
WAS A MAJOR FRUSTRATION
AT THE EXISTING SSP CAMPUS

2. **Room D5. Pre-Kindergarten Students**
Space is being used as a General Education Classroom for 4-5 year old students.

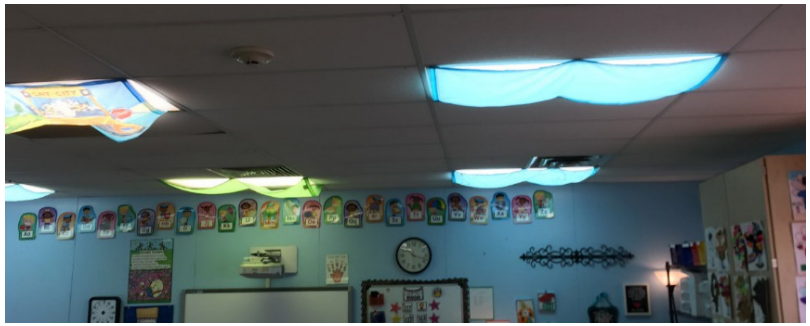
Room Observation: Walls and floors consist of neutral colors such as brown, beige, and tan. Space contains decoration artifacts and task lighting such as incandescent glass bulbs to set the mood in the space and make the kids feel at home. Room lights are usually off and several blankets are present in the ceiling spaces.

Lighting: Lighting in room consists of recessed fluorescent lights. No dimming control is available in room. Lights are usually off to reduce lighting levels for children that are hypersensitive to bright lights Hyperactivity in children is a major concern.

Min. Fc level with lights "OFF"

Max. Fc level with lights "OFF"

Excerpt from analysis of existing campus lighting



Existing classrooms with lights baffled, turned off, and supplemented with warm light from lamps

The new Shining Stars campus creates a rich indoor-outdoor learning environment that is specific to Shining Stars' needs. Each classroom wing has its own direct entrance to break down the scale of this large 30-classroom campus, minimize travel distances, and avoid overwhelming young children.

Thematic wayfinding based on natural habitats connects interior finish materials like tactile wood panels and felt shapes to outdoor entry colors and custom glass decals. Interior themes relate to the outdoor learning environments, so the desert-themed wing connects to an outdoor sand play area with dinosaur bones and fossils, and the forest -themed wing relates to an outdoor reading area with a turf-covered hill and tree trunk crawling tubes.

Each pair of classrooms promotes student independence and learning through shared restrooms, built-in casework with child-height displays, and an open layout to enable teachers to create a variety of learning centers. Shared central resources include a STEaM lab, distributed library, gross motor lab, fine motor lab, and calming sensory room.

Pod Themes

- *Space*
- *River*
- *Forest*
- *Desert*
- *Mountain*

During Schematic Design, it was determined that LED lighting in learning spaces throughout the building would be both dimmable, to vary intensity/type of lighting, and tunable, to allow teachers to adjust the color temperature for different needs.

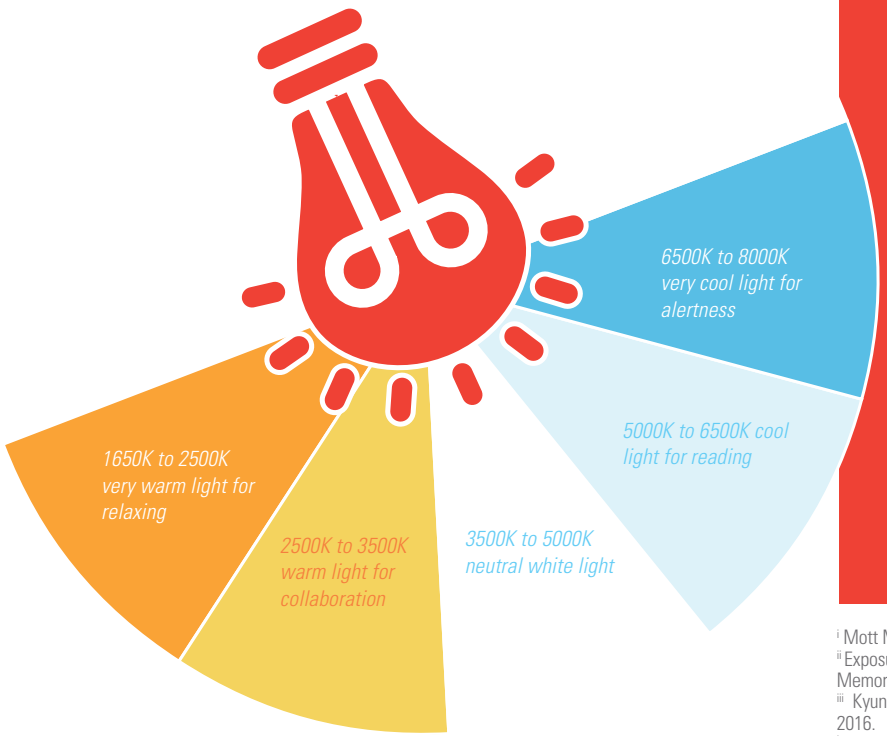
In order to allow each teacher full control over the lighting in their classroom, only the lighting in common spaces such as hallways is able to be controlled remotely by Facilities staff. Classroom dimming and color temperature is controlled by 2 simple slider switches in each classroom. The school district remained committed to implementing this system even when other building components were modified via value engineering discussions to control the overall project cost.

Multiple light fixture options and light switches/controls were evaluated using product data and physical samples to inform the final design and selection of the tunable fixtures, and a sample fixture was demonstrated to all SSP staff prior to the start of construction.

Top: SSP staff reviewing selected fixture
Bottom: evaluating sample fixtures to confirm desired temperature range and operation

Tunable Lighting

Tunable white lighting systems allow users to control the color temperature across a spectrum from warm to neutral to cool color temperatures. The specific range of color temperatures varies by product, but typically products cover both warm and cool light temperatures. Tunable LED lighting systems can allow both color tuning and dimming to provide widely varied lighting conditions.



Results from published studies on the impact of color temperature adjustments on student performance have reported that:

- Test scores of 3rd grade students that were exposed to 6500K lighting while practicing oral reading fluency improved at a much greater rate than students in a control group at 3500K lighting, even though all students were tested together at a lighting color temperature of 3500K
- Exposure of adults to blue light prior to performing a working memory task showed activation of parts of the brain related to cognition and mental control when viewed using MRI
- Math test scores of 4th grade students improved after switching from testing under fluorescent lighting to testing under tunable lighting, and the best test results were achieved with 6500K lighting
- High color temperature lighting improved self-reported alertness amongst students in afternoon lectures
- Test scores on standard tests which measure concentration increased after classrooms were changed from flurorescent lights to tunable white lighting in a high school in England
- Dutch 4th grade students in a room with 6500K lighting had greater improvement on concentration tests than students using 4000K lighting, but similar effects were not found for 6th grade students
- Student reading speeds increased, errors were reduced, and restlessness was reduced amongst elementary students in Germany using tunable lighting

Other studies focusing on tunable lighting use and perceived behavioral impact have reported that:

- 94% of teachers in 84 elementary classrooms in three separate buildings with tunable lighting self-reported that they had changed the color temperature of the lighting
- Over half of these teachers changed the color temperature more than twice during a typical day and 51% reported that they change color temperature based on activity
- In that same study, 37% of respondents indicated changes in student behavior associated with the tunable lighting, including helping students concentrate, focus, relax, and be calm
- Other studies have reported anecdotal benefits relating to student engagement in their environment and improved sleep/wake cycles

[i] Mott MS, Robinson DH, Walden A, Burnette J, Rutherford AS. Illuminating the Effects of Dynamic Lighting on Student Learning. SAGE Open. April 2012.
[ii] Exposure to Blue Wavelength Light is Associated with Increased Dorsolateral Prefrontal Cortex Responses and Increases in Response times During a Working Memory Task. Journal of Sleep and Sleep Disorders Research, Volume 39, 2016.
[iii] Kyungah Choi and Hyeon-Jeong Suk. Dynamic lighting system for the learning environment: performance of elementary students. OPTICS EXPRESS. April 2016.
[iv] E. Rautkylä, M. Puolakka, E. Tetri, and L. Halonen. Effects of correlated colour temperature and timing of light exposure on daytime alertness in lecture environments. Journal of Light & Visual Environment. Volume 34, 2010.
[v] David P Hakimi. (2011, August 15) 3 Ways Lighting Affects Students in The Classroom (And What To Do About It).
[vi] P. Sleegers, N. Moolenaar, M. Galetzka, A. Pruyn, B. Sarr 'oukh, and B. van der Zande. Lighting affects students' concentration positively: findings from three Dutch studies. Lighting Research & Technology. Volume 45, 2013.
[vii] N. Wessolowski. Wirksamkeit von dynamischem Licht im Schulunterricht. Dissertation (University of Hamburg). 2014.
[viii] NALMCO. (2019, August) It's Not Always About Circadian Rhythms, Tunable White in the Classroom.
[ix] Ibid
[x] Ibid

The lighting selected for Shining Stars Preschool is a direct/indirect high-efficiency LED fixture that provides color blending for a temperature range of 1650 to 8000K with a CRI (color rendition index) of 90+. It has an expected life of over 50,000 hours and easy to maintain 0-10V dimming drivers, and a 10-year warranty on the light fixtures themselves. The lighting controls have separate slider controls for dimming and temperature control, as well as a simple on/off control to return to the previous state. Each of the approximately 800sf classrooms have 12 of the 2'x2' lighting fixtures installed within a standard acoustical ceiling.

While the lighting combinations are endless, several examples were provided to teachers of how the dimming and color temperature controls might be used together as shown in the images above.

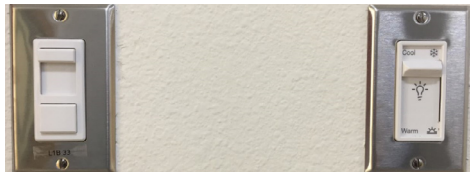
While energy efficiency wasn't the main reason for using tunable LED lighting, the dimmable LED lighting used in the new building was estimated to reduce demand by approximately 53% compared to the lighting used in the old facility, which was fluorescent lighting with T8 and T12 lamps, electronic ballasts, and no dimming capability.

Relaxation
Dim level low Temperature 1850K

Calming
Dim level high Temperature 1650K

Alertness
Dim level low Temperature 8000K

General
Dim level maximum Temperature 6000K



Lighting Use at Shining Stars

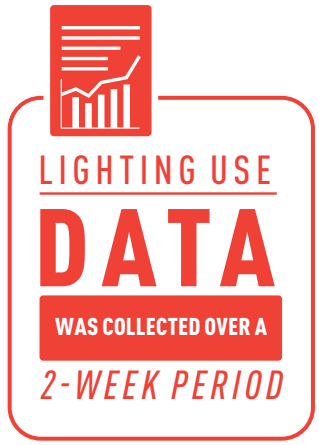
The start of in-person learning at the new campus was slightly delayed by COVID-19 restrictions. Once students were allowed in the building, the architect and electrical engineer for the new school met virtually with the full SSP staff to present information about the specifics of the new lighting system, a bit of background about light color temperatures, and the proposed method for collecting data.

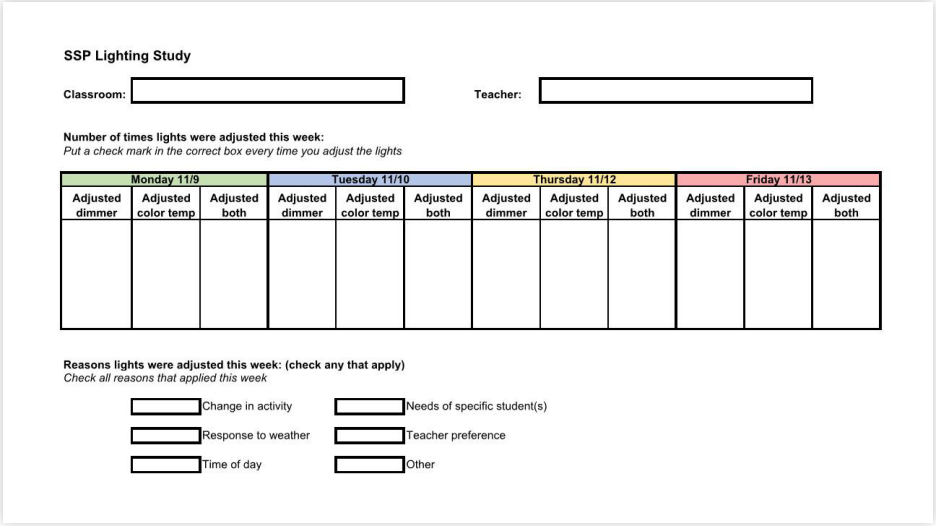
In order to provide an accurate account of lighting adjustments without relying on a teacher's recollection after the fact, simple logs were posted to the wall next to the lighting controls. Each teacher was asked to identify their classroom, and make a tick mark each time the dimmer, color temperature, or both were adjusted. Teachers were also asked to indicate the reasons that lights were adjusted that week. Lighting adjustments were logged over a 2-week period in all occupied classrooms. While Shining Stars typically operates two half-day sessions each day, due to COVID-19 restrictions the school was only occupied during the morning session during the time of this study.

This focus on both frequency of adjustment and reason for adjustment was intended to provide a true understanding of how the lighting system is being used. During design, the team discussed that human behavior can be unpredictable – teachers might adjust it daily in response to different activities or weather or the needs of specific children, or might leave the lights off regularly, or might find a preferred lighting level and no longer adjust the lighting. This uncertainty is increased by the fact that teachers have the option to control just dimming or just color temperature or both.

The selected methodology of collecting data via paper logs is interrelated to several other factors:

- The installed lighting controls are deliberately simple and manual, so that controls are directly in the hands of the teachers and cannot be overridden by others. This is in keeping with the school's goals but meant that it would not be possible to collect any information on lighting use/adjustment from a sophisticated control system.
- It may be possible to collect information on lighting levels and color temperature from sensors placed in rooms for the duration of the study – but this would be an added cost, may provide less accurate information due to natural changes in light through windows, and would not capture information about the reasons for lighting adjustment.
- The paper logs don't rely on recollection, but are subject to inaccuracy due to teachers completing them in different ways that could be misinterpreted – some put a single tick mark that may have indicated a single change or multiple adjustments in that period, some clearly indicated the number of adjustments each day, some indicated the time they made an adjustment, and some indicated when they left the lights completely off.





SSP Lighting Study

Classroom: _____ **Teacher:** _____

Number of times lights were adjusted this week:
Put a check mark in the correct box every time you adjust the lights

Monday 11/9			Tuesday 11/10			Thursday 11/12			Friday 11/13		
Adjusted dimmer	Adjusted color temp	Adjusted both	Adjusted dimmer	Adjusted color temp	Adjusted both	Adjusted dimmer	Adjusted color temp	Adjusted both	Adjusted dimmer	Adjusted color temp	Adjusted both

Reasons lights were adjusted this week: (check any that apply)
Check all reasons that applied this week

☐ Change in activity ☐ Needs of specific student(s)
☐ Response to weather ☐ Teacher preference
☐ Time of day ☐ Other

Simple data log used to track lighting adjustments

The data from the 2-week logging period indicates that:

- Teachers adjusted the dimmer most frequently (52% of adjustments), followed by adjusting both dimming and color temperature (28%), and adjusting only color temperature (20%)
- Other fairly common reasons for adjustment included teacher preference (21%), needs of specific students (17%), and time of day (17%)
- Only 4% of responses indicated that a lighting adjustment was made in response to weather, or for other reasons. Some teachers noted other reasons for adjustment including to create calm or transitions, to calm the vibe in the room, to lower lighting for a videoconference, or that a student played with the light switch.
- The logs did not indicate any significant difference in timing – all 3 types of adjustments were made each day of the week, and the half-day sessions due to COVID-19 restrictions prevented collection of full data across the length of the day
- The logs did not indicate any clear difference in adjustments based on building wing or solar exposure – frequency, type, and reasons for adjustments varied but with no clear pattern

Anecdotal responses from teachers about the initial use of the tunable lighting system included:

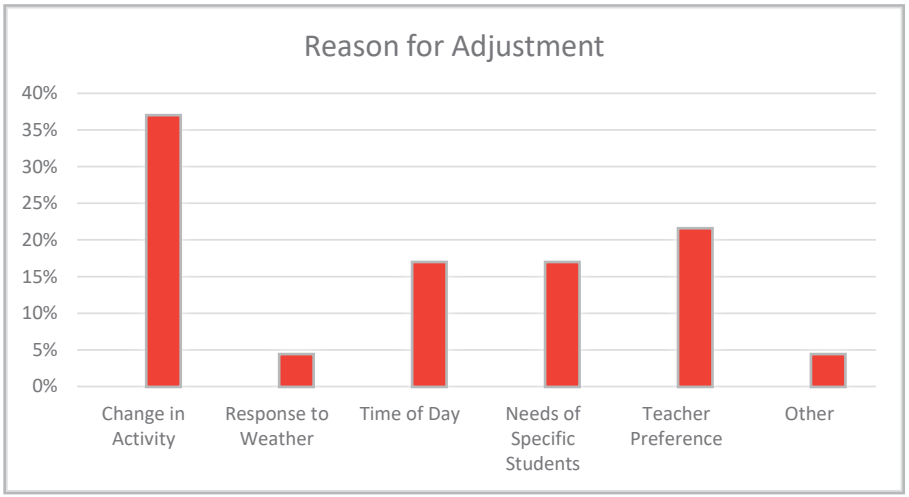
- "We have found a setting that we love – warm/home style. We feel relaxed and productive with our lighting choice. We are teaching virtually within a classroom. We love having our lights set to a warm/home-type setting. Due to no kids in class we keep the same setting at all times!"
- "Typically used to transition and help with focus for yoga/movement video, helps minimize distractions"
- "For Google Meets I have found that it has to be on high cool just to stop the shadows."
- "I like that there is not any flickering."
- "And a number of similar comments expressing appreciation for the system, such as "I absolutely love the lighting system", "I love the lighting change ability", and "I love being able to dim the lights!"

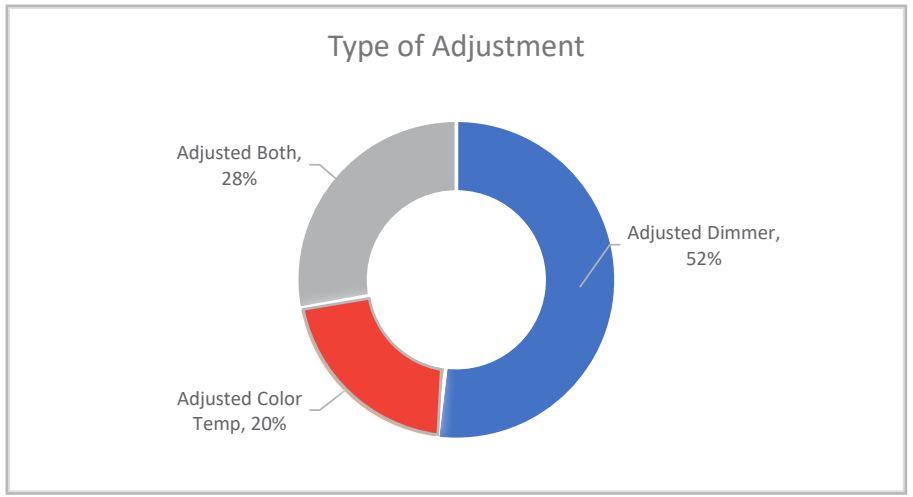
THE MOST COMMON REASON FOR

ADJUSTING LIGHTING

was due to a change in activity

(37% OF RESPONSES)





Conclusions & Further Study

Behavioral responses to lighting can be difficult to quantify, particularly with young children in a very flexible learning environment. As designers, we rely on the expert opinions of the teachers and educational experts that spend every day in the classroom observing their students. Installing a new type of lighting system that gives teachers more control over the learning environment may pose a small risk in terms of lighting cost and lack of familiarity, but the potential for tunable lighting to help reinforce learning and encourage desirable behaviors was considered worth the risk during design. The lighting system was an opportunity to directly apply the lessons from the previous facility's shortcomings to the design of the new school, and empower teachers to create a setting that best supports their students' activities and needs.

After the design was completed and the new school was under construction, the local fire marshal required that the light baffles in the existing school be taken down, since they had only been approved on a temporary basis two years earlier. Shining Stars staff reported that as soon as the baffles came down, they saw significant changes in student behavior, described as "the kids' engines were running so much higher" with existing lighting restored to full brightness. Staff kept the lights off most of the time to avoid this negative impact on students while awaiting the new building. While anecdotal, this reinforces that staff witness both positive and negative behavioral responses to changes in lighting, and that these responses seem to occur fairly quickly.

At this time it is unclear whether the initial usage patterns for adjusting dimming and color temperature will change over time. But it is clear that the system was well-received by school staff, that both dimming and color temperature are being adjusted, and that each teacher is making different choices about how to best use the tunable lighting system in their classroom. These benefits of adaptability and empowerment can be considered by educators and designers evaluating potential use of a tunable lighting system.

TAKEAWAYS FOR FUTURE PROJECTS

- Discuss **early in planning or design** whether the ability to tune color temperature might offer benefits in terms of mood, behavior, and productivity that align with project goals
- Determine **which spaces** can best benefit from this technology, since it is less to be beneficial in spaces with infrequent occupancy (such as hallways, bathrooms, storage rooms, etc.) or spaces in which a single, consistent type of activity occurs
- Use **physical lighting samples** to evaluate the extent of color temperature change that is desired, since different lighting products vary in how much of the spectrum is available
- Consider what metrics might be used to **judge the success or impact** of the tunable lighting system, such as casual user feedback or hard data about usage
- **Design lighting controls** to encourage use by occupants and simplify ongoing maintenance
- Provide **background information and training** on color temperature, system intent, and system use to building occupants, including quick reference information that can be used over time as new staff or occupants encounter the system

DEKKER
PERICH
SABATINI

505.761.9700
dpsdesign.org

BRIDGERS
& PAXTON

505.883.4111
bpce.com