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Abstract

Research addressing light technology has been conducted since the early 1900s primarily in industrial settings for determining how to make the workplace more productive. Presently, the role of how light technology impacts the workplace, home and community settings has broadened to include research on light for positively impacting education. The current review addresses lighting by learning in educational settings to date and focuses on the two latest light technologies of fluorescent and light emitting diodes (LEDs). Results of studies reveal that various light technical specifications lead to behavioral improvement, cognitive growth and achievement in oral reading fluency. Implications for educational administrators are offered to increase the efficacy of new lighting technology acquisition in schools.

Light is important to human beings. In fact, light is a basic need that is known to affect physical, and psychological behaviors in humans (Bellia, 2011) and overall wellbeing including alertness and sleepiness (Baron, Rea & Daniels, 1992). Aries, Aarts & Hoof (2013) note that humans have evolved while under the influence of the daylight and dark cycle. The researchers explain that humans overwhelmingly prefer to work and sit near windows, but there is no full explanation as to why. Potential reasons link to view of the outside, quantity and quality of light and the possible influence on human health.

Lighting system research and technology has transitioned over the years. As electronic and architectural evolutions occur, the type of lights humans use inside building environments has been opened to professional and personal preference in some buildings. The lighting evolution has included the use of direct sunlight, windows and sky vaults, incandescent, fluorescent, and LED bulbs (Bellia, 2011).

Light has been evaluated in work settings as well as in educational settings. In 2011, researchers studied four workplace lighting technologies and their effect on perception, cognition, and affective state (Hawes, Brunye, Mahoney, Sullivan, & Aall, 2012). This study found that individuals had increased cognitive reaction time and their mood state was reliable when lighting had been manipulated to varying color temperatures. Similarly, but in classrooms, a group of educational researchers found that varying the color temperature of lighting in classrooms had a positive effect on literacy skills in children (Mott, Robinson, Walden, Burnette & Rutherford, 2011; Mott, Robinson, Williams-Black, & McClelland, 2014)

Since Luckiesh and Moss (1940) documented increased achievement on test scores for 5th and 6th grade students in well-lit classrooms over students in regular or poorly lit classrooms, researchers have been studying the implications of classroom lighting. Lighting greatly influences the psychological well-being of students and teachers and also has an affect on behavior and academic outcomes of students.

School Lighting Environment

School environment design is significant. As one professor of architecture noted, "The data for the designing of public school buildings have been more completely standardized than for any other type of structure, except the American public library" (Hamlin, 1910, p. 3). Another author at the turn of the century stated, "the school building should be simple, dignified and plain and should be build of the most enduring materials…because the true character of the building will be expressed through such materials" (Mills, 1915, p. 34). As research and architectural design standards evolve it is important to look back at the trends of the past. It is also instructive to look to the future of school design, specifically how the design elements of lighting have evolved. In an extensive review of the literature regarding school design, Baker (2012) notes that prior to 1945 daylight was fundamental to school buildings primarily due to the lack of electricity in the structures. Baker further explains how lighting has evolved in the recent history noting incidentally lighting standards have remained largely the same since the 1959, utilizing both windows for natural light as well as newly added artificial (fluorescent) light.

Wall color is often determined by a school district, windows cannot be opened due to safety concerns, and light fixtures are often incandescent or fluorescent. Tanner (2008) acknowledges that the physical design of schools can affect student achievement. His study concluded that there are variances in achievement when students were exposed to design elements including lighting. Additionally, poor learning environments', including poor lighting conditions, can foster negative attitudes just as exceptional designs may boost achievement (Chan, 1996).

Quality of light varies in nature and classrooms as much as the individual's ability to see and focus can vary. Teachers seek to design the most beneficial environment conducive for student learning and productivity. Considerations of floor space, temperature, noise levels and lighting have solid research underpinnings for optimal learning space. As a result, all aspects of the classroom can be manipulated to enhance learning (Bettenhausen, 1998).

The impact of the classroom environment on educators and students is not ignored in past or current research. One of the most critical areas of this line of research focuses on classroom lighting. Lighting conditions within a classroom can be a significant source of impact in student performance and overall learning (Dunn, Krimsky, Murray & Quinn, 1985, Horton, 1972, Luckiesh & Moss, 1940).

Ott (1976) designed a pilot study to evaluate how full-spectrum fluorescent lighting, which emits a natural daylight spectrum, affected student behaviors. The study revealed that the use of cool white fluorescent light bulbs, with aluminum covering the ends of the lighting tubes to block soft x-rays in classrooms, improves the behavior of students who display hyperactive behaviors or have learning challenges. Furthering Ott's research, Grangaard, (1995) studied how color and light effected on and off task behaviors of students as well as their blood pressure. His study examined the effects of color and light on the learning of eleven six year olds enrolled in an elementary school. He videotaped students to identify off–task behaviors and also measured student blood pressure in two settings: a standard classroom using cool-white fluorescent lights and a classroom using full-spectrum Duro-test Vita-lite lights, which was considered the "modified" classroom. The study revealed that students in the modified classroom had lower blood pressure and exhibited fewer off-task behaviors.

Battles (2006) designed a quantitative study to determine the relationship of the effect of the use of full spectrum lighting on the increased achievement, attendance, sense of well-being, and on-task behavior in the special education student population. Instruments used were bi-monthly surveys, pre and post-tests, weekly grades, frequency counts of off-task behaviors, and attendance record. Paired T Test, ANOVA 1-WAY, and MANOVA were used as statistical analysis. Battles' analysis indicates that full spectrum lighting did enhance English, mathematics, and social studies achievement as well as on-task behaviors in the students he studied.

Tanner (2008) states that the physical design of schools can affect student's ability to learn. Likewise, Bishop (2009) received survey responses indicating that all responders agree that the amount of natural light incorporated into the design of a school facility has a positive impact on student and staff behaviors as well as student achievement.

Sleegers, Moolenaar, Galetzka, Pruyn, Sarroukh, & Zande (2013) conducted research for The Philips Corporation, an international diversified technology company focusing on lighting, to examine lighting variables of color temperature and illuminance for impacting: sleep, mood, focus, motivation, concentration, as well as work and school performance. The study reported an increased reading speed as well as cooperation level and reduced hyperactivity behaviors in children participating in the research.

Physiology of the Eye

Lisman (2015) explains that the brain is one of the most complex systems on Earth. He notes neuroscience has provided insight into how the particular networks can lead to particular firing patterns. One such network and pattern research explores is how the brain computes what the eye receives.

Friend (2014) describes the eye as a complex organ composed of three layers. The first layer is described as a protective layer. It includes the cornea and the sclera. The second layer of the eye is referred to as the uveal tract. This layer includes the iris, pupil, lens, ciliary body, aqueous humor, and the choroid. The innermost layer of the eye is called the retina. Simply, "If the eye were a camera, the retina would be the photosensitive film" (Oyster, 1999, p. 79).

The process of seeing an image through the eye is complicated. It begins with light rays entering the eye, traveling through the cornea, passing through the aqueous humor to the iris, continuing through the lens, where the rays are adjusted, and eventually landing on the retina where the image is focused (Friend, 2014). Faran (2000) explains that color and color quality of an image as perceived by the brain correspond to the physical property of the wavelength of color and are represented in the human nervous system as a profile of responses across cones, which absorb wavelengths of light to varying degrees.

For most people, the experience of color is similar. However, if an individual has visual perception difficulties, color could be perceived in a different way entirely. It could even provoke certain emotions or even amplify medical concerns (McGuiness, 2007). A new line of research regarding sight, lighting, processing and learning is growing. Recently there has been a research focus on the physical environment in the educational process.

Updating Classroom Lighting

Emerging technology with positive academic and behavioral implications supported by research is offering school systems more options for modifying the learning environment through lighting. Extensive research related to environment and lighting was conducted in school classrooms by Mott, Robinson, Walden, Burnette, & Rutherford (2012). These researchers hypothesized that offering lighting conditions that support children biologically, psychologically, or visually during literacy lessons would improve student achievement. The study evaluated how variable lighting settings affected the oral reading fluency of eighty-four third grade students in the mid-South region of the United States. Mott et al. (2012) specifically examined the “Focus” lighting setting, which consists of 1000 lux and a temperature of 6500 kelvin and emitting a bright white color, and the “Normal” lighting setting, which consists of 500 lux and a temperature of 3500 kelvin, emitting a natural white light. Student’s AIMSweb scores for both pre and post lighting treatment change were used as a measure of the effect for the lighting settings on oral reading fluency performance. The study found a significant positive effect on oral reading as well as behavior when classroom environment was modified by the use of a dynamic lighting system, which allows the teacher to control the color and intensity of the overhead lights in the classroom. Using a similar quasi-experimental design Mott, Robinson, Williams-Black, and McClelland (2014) evaluated the oral reading fluency gains of eighty-eight third grade students when using the “Focus” and “Normal” lighting settings. The results of the study support the findings in 2012, suggesting that variable artificial lighting does play a role in student achievement. Students who received instruction with the use of “Focus” setting did improve oral reading fluency at a greater rate than those students who were instructed under “Normal” lighting conditions. This finding suggests that situational lighting can create an environment with less stress on the student’s eyes and an overall comfortable environment to work and be successful.

Rating scales for lighting sources are measured through CCT (correlated color temperature) values range from warm to cool in appearance. Lux is referred to as the measure of illumination. According to Sleegers, Moolenaar, Galetzka and van der Zanden (2012) a connection between the CCT value and student performance exists. Classrooms with a “blue-rich white light” represented in a 12,000K CCT value can stimulate students and create an energetic atmosphere. Whereas, a room filled with a "warm, red color tone" with a CCT value of 2900K could translate to a more calming atmosphere. However, the traditional light used within a classroom is rated between a 3000-4000K CCT value. Lighting choices are also influenced by age. Younger children can adjust to a light due to their age that has some glare (Fielding, 2000).

Many experimental studies in the past have examined the effects of monochromatic light, which is a short-wavelength light representing only one light. Today, most indoor public places have polychromatic light that expresses a diverse spectrum of brightness and color temperature. It is thought that a diverse spectrum of brightness and color temperature may affect cognitive function, such as attention, executive function, and memory. In a recent study, researchers evaluated thirty-two subjects as they performed cognitive tasks while being exposed to four different polychromatic lighting conditions (Young, et al., 2013). In addition, two different levels of color temperature and brightness were implemented in the research environment. The outcome revealed that the interaction between color temperature and brightness affects alpha activity in the frontal and occipital areas. Therefore, based on the Kruithof curve both color temperature and brightness should be considered as optimal lighting for working environments such as colleges and schools.

Administrator's Implications

Given the body of research that is emerging, educational leaders must find ways to address the cost/benefit of moving away from artificial pink or cool-white fluorescent lighting, known as *malillumination* (Ott, 1976) to full spectrum lighting and color, known as *posillumination* (Martel, n.d.). Few school leaders consider themselves lighting experts; therefore, those seeking to make a significant impact on classroom environments may ask the following questions:

1. What does the research say about the effects of lighting on student achievement and behavior?
2. What do I need to know about lighting to move my school forward?
3. What are the costs associated with retrofitting my school and where do I locate the funds?
4. How will I measure success?

Research clearly documents that lighting affects student behavior and achievement with multiple studies providing methods to measure the success of moving to full spectrum lighting. However, the more difficult questions for school leaders to address are how do I move my school forward? What are the costs? And, where do I find the funds? Administrators must understand the true costs associated with moving their school forward; therefore, they should seek out lighting experts to assist in estimating the total cost of purchasing and maintaining lighting systems in all classrooms. Budgeting for initial replacement costs and retrofitting costs may require school leaders to seek out alternate funding opportunities to cover these initial costs.

Conclusion

In conclusion, this literature review offers insight into the history of lighting in schools and explores the academic benefits for variable lighting use in classrooms.

One practical inference to be drawn from the literature is to minimize the level of illumination (Kelvin) emitted by fluorescent tube lighting to create a calming classroom environment and potentially decrease adverse behaviors and improve mood. Future research implications include further experimental studies regarding lighting and academics, as well as an extension of research to include how variable lighting affects the behaviors and moods of children with behavior based disabilities. Continually extending the experimental research opportunities and results to support the literature could undoubtedly open an opportunity for grants and agency funding to support modernization and modification of school lighting use and design.

References

Aries, M. B. C., Aarts, M. P. J., & van Hoof, J. (2015). Daylight and health: A review of the evidence and consequences for the built environment. *Lighting Research Technology*, *47*, 6-27.

Baker, L. (2012). A history of school design and its indoor environmental standards, 1900 to today. National Clearinghouse for Educational Facilities. Retrieved from http://eric.ed.gov/?id=ED539480

Baron, R. A., Rea, M. S. & Daniels, S. G. (1992). Effects of indoor lighting (illuminance and spectral distribution) on the performance of cognitive tasks and interpersonal behaviors: The potential mediating role of positive affect. *Motivation and Emotion, 16*, 1-33.

Battles, A. B. (2006). The use of full spectrum lighting to enhance academic achievement, attendance, sense of wellbeing, and on task behavior in the special education student population (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses database.

Bellia, L., Bisegna, F., Spada, G. (2011). Lighting in indoor environments: Visual and non-visual effects of light sources with different spectral power distributions. *Building and Environment. 46*, 1984-1992.

Bettenhausen, S. (1998). Make proactive modifications to your classroom. *Intervention in School and Clinic, 33* (3), 182-183.

Bishop, M.E. (2009). A Case Study on Facility Design: The Impact of New High School Facilities in Virginia on Student Achievement and Staff Attitudes and Behaviors. (Unpublished doctoral dissertation). The George Washington University, Washington,D.C.

Chan, T. C. (1996). Environmental impact on student learning. Retrieved from http://eric.ed.gov/ERICWebPortal/Home.portal;jsessionid=HwnVGyBDgy9NhJG1H116JTk4TokkyTpywbjQz5r8DFCXHJYqvM1209635?_nfpb=true&ERICExtSearch_SearchValue_0=%22Chan+T.+C.%22&ERICExtSearchType_0=au&_urlType+action&_pageLabel==ERICSearchResult

Dunn, R. Krimsky, J.S., Murray, J.B., & Quinn, P.J. (1985). Light up their lives: A research on the effects of lighting on children's achievement and behavior. *The Reading Teacher, 38*(19), 863-869.

Faran, M. J. (2000). *The cognitive neuroscience of vision*. Malden, MA: Blackwell Publishing.

Felding, R. (2002) Lighting the Learning Environment. Design Share. Retrieved from http://www.designshare.com/Research/Lighting/LightingEnvr1.htm

Friend, M. (2014). *Special education: Contemporary perspectives for school professionals*. Boston, MA: Pearson Publishing.

Grangaard, E. M. (1995). *Color and lighting effects on learning*. (Research Report No. 143). Retreived from http://files.eric.ed.gov/fulltext/ED382381.pdf

Hamlin, A. (1910). *Modern school houses; being a series of authoritative articles on planning, sanitation, heating and ventilation*. New York, NY. The Swetland Publishing Co.

Hawes, B., Brunye, T., Mahoney, C. Sullivan, J., Aall, C. (2012). Effects of four workplace lighting technologies on perception cognition and affective state. *International Journal of Instustrial Ergonomics, 42*(1), 122-128.

Horton, C.D. (1972). *Humanization of the learning environment*. Arlington, VA. (ERIC Document Reproduction Service No. ED066929).

Lisman, J. (2015). The challenge of understanding the brain: Where we stand in 2015. *Neron, 86*, 864-882.

Luckiesh, M. & Moss, F.K. (1940). Effects of classroom lighting upon the educational progress and visual welfare of school children. *Illuminating Engineering, 35*, 915-938.

Martel, L. D. (n.d.) *Light: An element in the ergonomics of learning*. Retrieved from http://www.fullspectrumsolutions.com/lighting_for_schools.shtml

McCreery, J. & Hill, T. (2012) Illuminating the Classroom Environment. *Lighting Associates*. Des Moines, IA. Retrieved from http://www.lightingassociates.org/i/u/2127806/f/tech_sheets/illuminating_the_classroom_enviroment.pdf

McGuiness, L. (2007). The healing power of colour. *Positive Health, 11,* 14-16.

Mills, W.T. (1915). *American School Building Standards*. Los Angeles, CA: Franklin Educational Publishing Co.

Mott, M. S., Robinson, D. H., Walden, A., Burnette, J., Rutherford, A. S., (2012) Illuminating the Effects of Dynamic Lighting on Student Learning. Sage Open. Retrieved from http://sgo.sagepub.com/content/2/2/2158244012445585

Mott, M. S., Robinson, D. H., Williams-Black, T. H., & McClelland, S. S. (2014). The supporting effects of high luminous conditions on grade 3 oral reading fluency scores. Retrieved from http://www.springerplus.com/content/pdf/2193-1801-3-53.pdf

Ott, J. N. (1976). Influence of fluorescent lights on hyperactivity and learning disabilities. *Journal of Learning Disabilities*. *9*(7), 22-27.

Oyster, C. (1999). *The human eye: Structure and function*. Sunderland, MA: Sineauer Associates, Inc.

Sleegers, P.J.C., Moolenaar, N.M., Galetzka, M., Pruyn, A., Sarroukh, B.E. & Zande, B. (2013). *Lighting affects students' concentration positively: findings from three Dutch studies.* Lighting research & technology, *45*(2). 159-175.

Tanner, K. C. (2008). Explaining relationships among student outcomes and the school's physical environment. *Journal of Advanced Academics*, *19*(3), 444-471.

Young Park, J., Ha, R.Y., Ryu, V., Kim, E., & Jung, Y.C. (2013). Effects of Color Temperature and Brightness on Electroencephalogram Alpha Activity in a Polychromatic Light-emitting Diode, *Clinical Psychopharmacology and Neuroscience, 11*(3), *126-131.*

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