I, Jessica Kestler, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Educational Studies.

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How Does Pre-Sleep Usage of LED Screen Technology Affect Sleeping Behavior and Academic Achievement?

Student’s name: Jessica Kestler

This work and its defense approved by:

Committee chair: Linda Plevyak, Ph.D.

Committee member: Anna Dejarnette, Ph.D.

Committee member: Ellen Lynch, Ed.D.
How Does Pre-Sleep Usage of LED Screen Technology Affect Sleeping Behavior and Academic Achievement?

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by

Jessica L. Kestler
MS, Ohio University, 2010
BS, Ohio University, 2008

Committee:
Linda Plevyak, PhD, Chair
Anna F. DeJarnette, PhD
Ellen Lynch, PhD
Abstract

The use of LED technology before bedtime reawakens the brain due to the blue light that emulates daylight. This delays sleep onset causing sleep deprivation, which affects academic achievement for college students. To date, no current studies explore how all three variables are influenced by one another. College students (n = 151; mean age = 20.35) were recruited to complete a weekly sleep journal to determine the impact that usage of LED technology has on sleep and the resulting influence on academic achievement. Participants also completed existing measurement questionnaires (Epworth Sleepiness Scale [ESS], Motivated Strategies for Learning Questionnaire [MSLQ], & 3x2 Achievement Goal Theory [AGT]) to assess how sleep deprivation influences daytime sleepiness and motivational strategies for mastery learning and achievement goals.

Kolmogorov-Smirnov (K-S) was first conducted to test whether parametric and non-parametric statistics were more applicable for the data. Then, partial least squares structure equation modeling software “SmartPLS”, was used to perform path analysis to examine the significance of the stated hypotheses. Most notably, results indicated that students who reported increased usage of LED light technology before bed reported increased time falling asleep and decreased total sleep duration. Increased focus during and outside of class was significantly positively associated with longer sleep duration and lower levels of LED technology usage before bed, but no significance was found between sleep duration and other academic achievement measures (i.e., MSLQ and AGT). Finally, no significance was found between time falling asleep and sleep duration. Collectively, these findings suggest that increased usage of LED technology before bed increases time to fall asleep, and students who reported increased academic achievement (focus) in
school also reported a decreased usage of LED technology before bed and increased sleep duration.
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Chapter One

Introduction

College can be one of the most fulfilling, enlightening, enriching, and advantageous opportunities a student may experience in his or her academic career. For many, it is the final stage of education that prepares students for real-world endeavors which includes challenging academic requirements, strategic time management, focused concentration, continual perseverance, and a diligent commitment to school work. College also provides freedom from parental constraints, independent lifestyles, increased domestic responsibilities, social activities, potential work obligations, cooperation with roommates, and newfound distractions (e.g., excessive noise, social pressure) (Buboltz, Soper, Brown, & Jenkins, 2002). College is a time of self-growth, exploration, autonomy, and possibility, and is a milestone event that encompasses an array of discovery. Attending college, however, comes with the added cost of rising tuition fees and inflated student debt, and therefore it is critical students be as efficacious as possible. As a result, understanding the issues that prevent students from maintaining their focus on academics is essential.

One developing area of research related to students’ academic success is the exploration of technology use on academic performance. Every day, college students are using smartphones, televisions, laptops, and tablets for either work-related functions or leisure, especially before bedtime (Chang, Aeschbach, Duffy, & Czeisler, 2015; Demirci, Akgonul, & Akpinar, 2015; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015). Currently, these technological devices are being manufactured with light emitting diodes [LED] that project the same wavelength as daylight (Lack & Wright,
which causes melatonin suppression during bedtime hours (Cajochen et al., 2011; Chang, Aeschbach, Duffy, & Czeisler, 2015; Lougheed, 2014; Wood, Rea, Plitnick, & Figueiro, 2013) resulting in sleep deprivation (Chang, Aeschbach, Duffy, & Czeisler, 2015; Lemma, Berhane, Worku, Gelaye, & Williams, 2014; Lemola, Perkinson-Gloor, Brand, Dwald-Kaufmann, & Grob, 2015) and poor academic achievement (Brown, Buboltz, & Soper, 2002; Brown, Soper, & Buboltz, 2001; Perkinson-Gloor, Lemola, & Grob, 2013).

Increased usage of LED technology devices before bed delays melatonin onset and therefore alters sleep patterns and increases sleep deficiency. This results in substantial detriments to academic achievement, complex cognitive tasks, memory retention, and higher cognitive functioning. In fact, college students are among the most sleep deprived age groups in the nation (Wolfson & Carskadon, 2003; Lund, Reider, Whiting, & Prichard, 2010; Adams et al., 2016). Most research studies have been conducted on middle-school and high-school student sleep deprivation, but there remains a significant lack of information about the effects on the college population. This is concerning because Oginska and Pokorski (2006) found that university students (18-27 years old) need approximately “8 hours and 22 minutes” of sleep compared to “7 hours and 37 minutes” for young employees (30-45 years old) and “9 hours and 23 minutes” for adolescents (14-16 years old) (p. 1317), yet 25% of college students are reporting less than 6 hours of sleep per night and 70.6% report obtaining less than 8 hours per night (Lund, Reider, Whiting, & Prichard, 2010). Moreover, daytime sleepiness was reported by nearly 50% of college students compared to 36% of adolescents and adults (Oginska
and Pokorski, 2006, p. 1322). Although research on the effects of technology usage, sleep deprivation, and academic achievement have been explored individually, there remains a very limited amount of research on how LED light technology used specifically by the college population before bedtime alters sleep patterns and affects their academic achievement.

Statement of Problem

If college students are spending more time staying awake because of technology usage, less time studying or sleeping, or are experiencing reduced quality sleep, an important question among educators, students, product manufacturers, and parents should be: how is usage of technology prior to sleeping affecting students’ quality and quantity of sleep, cognitive performance, and academic achievement? The purpose of this dissertation is to examine the relationships among college student self-reports of pre-sleep technology usage, sleep patterns and behavior, and existing scales of academic achievement. Because technology has become an integral part of college students’ lives, it is critical to more fully understand the impact it has on their sleep and academic achievement.

Research Questions

In order to explore the impact of technology use on academic performance, this study is guided by the following research questions: 1) How does usage of LED light technology and sleep duration correlate with academic achievement? 2) What is the relationship between LED light technology usage and academic achievement among college students with similar sleep duration? & 3) What is the relationship between sleep
duration and academic achievement among college students with similar LED light technology usage?

**Hypotheses**

The following hypotheses were used in this study to compliment the research questions: 1) College students who report increased usage of LED light technology before bed will report increased time falling asleep and decreased total sleep duration, 2) College students who report increased time falling asleep will report decreased sleep, and decreased academic achievement, & 3) College students who report increased levels of academic achievement, will report increased total sleep duration and decreased usage of LED light technology before bed.

**Assumptions**

A clear understanding of the various assumptions in this study offers greater insight and significance for the research topic. First, data collection was obtained through an online survey database with the assumption that participants responded truthfully and accurately to self-reports. To further emphasize this point for participants, preservation of anonymity and confidentiality was explained to volunteers who had the option to withdraw from the study at any point in time without ramifications. Because the participants for this study were college students, it was assumed that the sample was an accurate representation of the wider population and findings will be generalizable to similar groups. It was also assumed that during the data collection process, participants would accurately quantify and report their pre-sleep engagement with LED light technology in addition to truthfully reporting their weekly sleeping behavior, and sleep disruptions.
Limitations

There are several limitations that exist within this study. First, the use of self-reported surveys may encourage participants to exaggerate their answers and provide responses that are not completely truthful. Second, participants were gathered from a single university in one department. This may skew results as students in different universities have varying pre-sleep LED light usage, sleep patterns, and academic behaviors. Additionally, students in affluent universities may possess greater variations of LED light technology, which would increase their overall usage rate than the national average.

Operational Definition of Terms

For the purpose of this study, the following definitions were used for each of the important terms.

Academic achievement. This term has also been referred to as achievement motivation or achievement goals; refers to a desire for mastery learning and/or academic excellence for its own sake without a need for any external reward(s) to validate accomplishments or success (Atkinson, 1957).

Academic performance. This term has also been referred to as performance motivation or performance goals; focused on self-objectives, such as receiving external rewards or favorable judgments from others. The drive or need to present oneself as competent to others (Elliot & Church, 1997; Elliot & McGregor, 1999).

Adolescence. The adolescent population is approximately between the ages of 13 to 17 years old (Liu, Ma, Kurita, Tang, 1999). The transitional phase between childhood and adulthood that begins with puberty.
Circadian rhythm. Any rhythm in the body with a period of one day (24-hours), which is obtained from the daily cycle of daylight and darkness because of the earth’s axis spin. Circadian rhythm schedules vary among species, but most bodily functions rise and fall with daily rhythms, body temperature, blood flow, urine production, hormone levels, hair growth, and metabolic rate (Bear, Connors, & Paradiso, 2007).

Critical thinking. Taking an objective standpoint on newly acquired information that is evaluated on its merit and/or its validity and reliability to then make a decision through logical examination of the problem and the evidence (Nokes, Dole, & Hacker, 2007).

Daysimeter. A lightweight, portable headband device that records optical radiation from the visual and the circadian systems. This device logs spectral weighted radiation measurements, head positions, and motion as a representation of human circadian activity (Bierman, Klein, & Rea, 2005).

Declarative memory. The ability to recall a wide range of specific facts, events, rules, or generalities through embedded neural organization like a mental filing system (Greene & Azevedo, 2009).

Delayed sleep phase disorder (DPSD). In this context, DSPD pertains to a shift in the circadian rhythm in which the onset of sleep is delayed oftentimes past midnight, resulting in a late morning rise time (Yeh, Wu, & Cheng, 2010). Ailment is most associated with changes in geographic locations, increased evening activities, irregular sleep patterns, and/or a source of light stimulation that prohibits the onset of melatonin.

Early adults. The stage of early adulthood has been categorized between the ages of 18 to 22 years old (Liu, Ma, Kurita, Tang, 1999).
Electroencephalogram [EEG]. This is a non-invasive electrophysiological test that monitors and evaluates electrical brain activity using a head cap containing electrodes that are placed along the scalp. Brain cells communicate through electrical impulses and the electrodes track and record the brain wave patterns (Dresler et al., 2012).

Eveningness. An extremely delayed sleep period (Caci, Robert, & Boyer, 2004).

Evening-preferred chronotype. The propensity, either due to environmental or genetic predispositions, to fall asleep later in the evening and rise later in the morning (Golombek & Cardinali, 2008).

Executive function. A set of cognitive methods and practices that require the incorporation of working memory, inhibition, planning, execution, self-monitoring, assessment, and self-correction to achieve objectives during cognitive challenging circumstances (Welsh, Friedman, & Spieker, 2008).

Insomnia. This common sleep disorder pertains to the difficulty of falling asleep or staying asleep. This problem can be either acute or chronic. Side effects can range from daytime sleepiness, reduced energy levels, irritability, lack of focus or concentration, depressed mood, and decreased memory retention (Slater & Steier, 2012).

LED technology. This stands for, light-emitting diodes, which presents a high proportion of short-wavelength light. LED light appears blue because it is the same wavelength as daylight (468nm) on the color spectrum, which enhances alertness, awareness, and a feeling of being more awake (Yeh, Wu, & Cheng, 2010).

Melatonin. This chemical hormone is produced and released from the pineal gland to regulate sleep and wakefulness (Wood, Rea, Plitnick, & Figueiro, 2013). Melatonin secretion rises approximately two to three hours before regular bedtime to
keep bodily functions synchronized to circadian rhythm cycles (Figueiro & Overington, 2016).

Memory consolidation. Memory formation is a daily process of brain plasticity through synaptic associations of stimuli. Long-term memory consolidation is an evolutionary progression of consolidation that takes continual, uninterrupted time. This process is the most integrated and enhanced during nocturnal sleep (Walker, Stickgold, Alsop, Gaab, & Schlaug, 2005).

Metacognition. A process of learning and growth in which the awareness of an approach to complete a task or problem is implemented and then evaluated for its effectiveness (Zimmerman, & Risemberg, 1997).

Micro-sleeps. This temporary episode of sleep can last for a half a second or up to 30 seconds (Poudel, Innes, Bones, Watts, & Jones, 2014). This brief loss of awareness after a short delay in consciousness is often classified as a shift in EEG brain waves. Micro-sleep can be recognized by droopy eyes, slow eyelid-closure, or head nodding.

Morningness. An extremely advanced sleep period that induces an early rise time (Caci, Robert, & Boyer, 2004).

Morning-preferred chronotype. The propensity, either due to environmental or genetic predispositions, to fall asleep earlier in the evening and rise earlier in the morning (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002).

Neuron formation. This is also referred to as adult neurogenesis. This process involves the birth of neurons that are generated from undifferentiated neural stem cells. Through mitosis, these cells can function in learning, memory, and emotions. Once
generated, these cells can shape or reshape existing neurons in the brain (Cameron, & Glover, 2015).

Non-REM sleep. “An idling brain in a movable body” (Bears, Connors, & Paradiso, 2007, p. 595). This sleep stage is characterized by large, slow brain waves, with a rarity of dreams and some muscle tone. The body is capable of movement during this phase; however, the brain would only provide minimal commands related to movement or repositioning. Temperature, energy consumption, heart rate, respiration, and kidney function all slow down while digestive processes speed up. Mental processes hit their daily low in non-REM sleep (Bears, Connors, & Paradiso, 2007).

Optic chiasm. The structure in which the right and left optic nerves converge and partially cross to form the optic tracts (Bears, Connors, & Paradiso, 2007).

REM sleep. “An active, hallucinating brain in a paralyzed body” (Bears, Connors, & Paradiso, 2007, p. 595). This stage of sleep is characterized by low-amplitude, high frequency brain waves (EEG waves), vivid dreams, rapid eye movements, and the loss of muscle tone (Bear, Connors, & Paradiso, 2007). REM sleep is for dreaming, making brain waves appear identical to an active, waking brain (Bears, Connors, & Paradiso, 2007).

Sleep deprivation. The total number of hours slept relative to the recommended amount required per age group. A reduction in total hours of sleep obtained a night is a result of conflict between our internal biological clocks and the demanding schedules of societal constrains (Gradisar et al., 2013).

Suprachiasmatic nucleus (SCN). A small nucleus of the hypothalamus just above the optic chiasm that receives retinal innervation and synchronizes circadian rhythms.
with the daily light-dark cycle (Bear, Connors, & Paradiso, 2007). Removal of the SCN will abolish the circadian rhythms of physical activity, sleeping and waking, and feeding and drinking. The brain’s internal rhythms never return without the SCN, but instead will coordinate new schedules with light and dark cycles.

Surface electromyography [SEMG]. A surface-level evaluation of muscle functioning by assessing muscle activity recordings above the skin.

Technological devices. This pertains to any form of electronic media. However, for this study, technological devices refers to smartphones, cell phones, televisions, tablets, iPad, laptops, or desktops.

Technostress. A personal reaction from trying to manage interacting with technology and the way in which society is changing due to technological innovations and influences (Arnetz & Wikholm, 1997).

Wake maintenance zone. A period of circadian rhythm cycling of phasing into a state of wakefulness after a prolonged period of staying awake. This has also been referred to as a second wind (Cajochen, Wyatt, Czeisler, & Dijk, 2002).

Working memory. A present state of mental processing that involves the engagement of effort to hold a certain number of items in the mind while simultaneously monitoring and manipulating those items (Klingberg, Forssberg, & Westerberg, 2002). In the remainder of this paper, Chapter Two will delve into existing research to address gaps in the research followed by the various theoretical frameworks that support this study. The literature review will discuss the individual aspects and the relationships between LED technology, sleep deprivation, and academic achievement. A greater understanding will be provided of how usage of LED light technology before bedtime suppresses melatonin, shifts the circadian rhythm, delays sleep onset, reduces sleep duration and sleep quality, which
limits memory and learning neural processing during REM sleep, leading to poor alertness and focus necessary for academic achievement.

Chapter Two will also discuss the theoretical framework along with both measurement scales and components of LED light technology, in addition to how interaction with those devices influence sleep and academic achievement. The first scale discussed, the Epworth sleepiness scale, is used to evaluate sleep propensity in every day situational contexts. Next, the external aspects that affect or are affected by sleep deprivation will be explored, with specific regard to excessive daytime sleepiness and LED light technology. Then, the neural cognitive affects that sleep deprivation has on memory consolidation and learning acquisition, with an emphasis on the importance of REM sleep, will be discussed. Finally, the motivated strategies for learning questionnaire (MSLQ) and the 3x2 achievement goal theory (AGT) are the final measurement scales used to assess academic achievement in this study. Elaboration of motivation, learning strategies, performance-based and mastery-based goal orientations towards academic achievement will also be explored.

Chapter Three will expand upon the research methods, including the population, instrumentation, explanation for the choice of data analysis, process of data collection, data benefits, and data limitations. Research procedures will revolve around addressing the primary research questions: 1) How does usage of LED light technology and sleep duration correlate with academic achievement?; 2) What is the relationship between LED light technology usage and academic achievement among college students with similar sleep duration?; 3) What is the relationship between sleep duration and academic achievement among college students with similar LED light technology usage?
Chapter four will present the results and analysis of the study. Chapter five provides a summary of the research findings, practical implications, limitations, recommendations for future research, and a conclusion to the results of the study.
Chapter Two

**Literature Review**

Puberty introduces an innate biological shift of sleeping patterns that naturally delays bedtime to later evening hours with adolescents and early adults needing eight to nine hours of sleep per night (Calamaro, Mason, & Ratcliffe, 2009). Although the exact age at which this delay develops is unknown, it has been found to continue into early adulthood (Oginska & Pokorski, 2006). Sleep alterations in younger adolescents (ages 12-17) have been extensively documented in comparison to sleep pattern changes during college. Relatively little is known about the factors that impact sleep difficulties and the resulting effects on learning acquisition and academic success for this population (Lund, Reider, Whiting, & Prichard, 2010). During a time of minimal adult supervision, erratic schedules, and greater academic demands, more understanding about the underlying issues that influence this population is vital for improvement.

**Technology**

To date, technological devices have become equally as disruptive to sleep onset as innate biological factors or any other form of external stimuli (Cain & Gradisar, 2010; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015). “Nearly all adolescents have at least 1 electronic item such as a television, computer, telephone, or music device in their bedroom…on average, 6th-graders have more than 2 of these items in their bedrooms, whereas 12th-graders have approximately 4” (Calamaro, Mason, & Ratcliffe, 2009, p. e1005). Generation Y (19-29 years old) best aligns with the college population and is second only to Generation Z (13-18 years old) in their excessive use of
technological devices within the hour before sleep (National Sleep Foundation, 2011).

A national survey of 1,508 participants between the ages of 13-64 found that Generation Y subjects (19-29 years old) demonstrated some of the heaviest usage of technology devices one hour prior to bedtime particularly with television (59%), smartphones (67%), computers or laptops (60%), electronic media devices (radio, mp3 player, iPod, etc.) (43%), and E-book readers (7%) (National Sleep Foundation, 2011, p. 14). While using these technological devices one hour prior to bedtime, Generation Y has expressed involvement in one or more of the following activities every night of the week: watching TV (49%), homework (38%), surfing the Internet (47%), using a social networking site (42%), sending or receiving texts (42%), doing work on a computer/laptop (24%), sending or receiving personal emails (20%), talking on the phone (22%), watching a video on non-TV device (computer/laptop/cell-phone, etc.) (18%), listening to music on an mp3 player or iPod (15%), sending or receiving work-related emails (10%), playing a video game or computer game (9%), reading on an E-book reader (3%) (National Sleep Foundation, 2011, p. 21). The resulting effects of sleep deprivation are that nightly sleep has “decreased 1 to 2 hours over the last 4 decades, with a twofold increase in adolescents sleeping <7 hours per night” (Calamaro, Mason, & Ratcliffe, 2009, p. e1005), which increases daytime sleepiness, depresses mood levels, and leads to lower grades. Students who are obtaining adequate sleep are “earning A’s and B’s in school” (Gaultney, 2010, p. 91).

Calamaro, Mason, and Ratcliffe (2009) examined one hundred adolescents (12 to 18 year olds) and found:

82% of adolescents watched 1 to 8 hours of television after 9 p.m. with 1.5 hours
watched on average. After 9 p.m., 34% of the adolescents reported text messaging, 44% reported talking on the telephone, 55% reported being online, 24% played computer games, 36% watched movies, and 42% listened to an MP3 player. An average of 1 to 2 hours was spent on each of these activities. On average, adolescents engaged in 4 technology activities after 9 p.m. (p. e1007)

Individuals who use multiple devices at once have shown the greatest decrease in total hours of sleep resulting in “changes in school performance, difficulties with executive function, and degradation of neurobehavioral function” (Calamaro, Mason, & Ratcliffe, 2009, p. e1008). Students who receive the least amount of sleep also consume the greatest quantities of caffeine at night. This aids in their inability to stay awake during the afternoon and/or in class, keeping them in a cyclical state of lacking the ability to then fall asleep at night. Students are often unaware about the severity of their sleep deprivation and how it is obstructing their ability to learn new material through accommodation with existing memories and neural connections (Gaultney, 2010, p. 91).

Engagement with just one technological device, depending on the light level intensity, will delay the production of melatonin, leading to sleep problems, insufficient attention and performance capabilities, impaired health, altered mental and emotional states, and unstable mood levels (Gaultney, 2010).

**Smartphones**

The introduction of the smartphone in the late 2000's captivated society, particularly the youth, because of its ability to enhance virtual connectivity, run at extremely high speeds to accommodate their stimulation needs through instantaneous gratification, and multifunctional capabilities (Skierkowski & Wood, 2012). This device
quickly overshadowed traditional phones because it still allowed consumers to access conventional cell phone functions (i.e., texting, phone calls) in addition to the innovative features of Internet and third-party software (e.g., apps, games). Prior to the smartphone, traditional cellphones were not advanced enough to allow for fully functional mobile keyboards or touchscreens that facilitated immediate mobile interaction among the youth population. These features became quickly appealing to adolescents because they created a new experience of arousal from direct mobile response communication between peers. This eliminated any unwanted pressures of face-to-face social interaction along with reducing the need for physical engagement with others to ensure sustainability of relationships or friendships (Skierkowski & Wood, 2012).

In 2016, it was reported that 92% of U.S. young adults (aged 18-29) owned a smartphone compared to 88% of adults (aged 30-49), 74% of adults (aged 50-64), and 42% of adults (aged 65+). (“Mobile Fact Sheet,” 2017). Because smartphones are affordable, handheld, portable devices that provide a connection between social and global affairs, college students consider their smartphones to be an essential part of their daily lives.

Conversely, because smartphones are easily accessible, students express an obligation to remain constantly available, regardless of their environmental surroundings or competing demands of school-related commitments (e.g., class, homework, studying) (Thomee, Dellve, Harenstam, & Hagberg, 2010). Unlike other technological devices or forms of mobile telecommunication, smartphones stand alone as offering the highest probability for uninterrupted, endless access (Murdock, 2013). This is not surprising because 42% of young adults (aged 18-29) report that they are texting within one hour of
going to sleep every night and 38% report that they sleep with their smartphones in their bedroom, with their ringers turned on (Smith, Rainie, & Zickuhr, 2011).

This causes tremendous “technostress,” (Arnetz & Wikholm, 1997). This is the inability to effectively cope with the use of innovative technological devices, which alters habitual tasks and priorities due to a compulsive need to stay connected (Arnetz, 1997, p. 97). Technostress creates anxiety about the need to keep pace, share updates, multi-task, and remain constantly available (Thomee, Dellve, Harenstam, & Hagberg, 2010). Technostress can lead to psychophysiological stress, such as, “mental overload, neglect of other activities and personal needs, time pressure, role conflicts, guilt feelings, social isolation, and physical symptoms” (Thomee, Dellve, Harenstam, & Hagberg, p. 1), consequently creating unending sleep disturbances.

Lin and Peper (2009) conducted a study on such psychophysiological issues associated with smartphones and text messaging. Twelve college students who had four or more years of daily texting experience were monitored with a surface electromyography (SEMG) from their shoulder to their thumb. While completing questionnaires and engaging in text messaging, the SEMG recorded respiration/abdominal breathing, blood volume pulse, finger temperature, and skin conduction. Results demonstrated that participants experienced a significant increase in all four areas compared to baseline levels along with holding their breath, shallow breathing, and experiencing arousal when sending and receiving texts which increased hand/neck pain and muscle discomfort. Participants were “automatically and unconsciously stabilizing their trunks, tightening their neck and shoulders, and breathing shallowly as well as thrust their heads forward in order to read the small screens” (p. 57).
Smartphones and other small portable devices demand concentration and vigilance while performing fine motor movements. The long-term health consequences of musculoskeletal disorders, pain, or repetitive injury strain need to be further explored as greater engagement with digital devices is increasing, starting in early childhood.

Frequent cell phone use can progressively compromise health and well-being and potentially cause additional neurological symptoms like depression, sadness, irritability, headaches, anxiety, loss of memory, and lack of sleep (Acharya, Acharya, & Waghrey, 2013). Collectively these issues create a physiological state that is not conducive to relaxation, and consequently, creates more stress, leading to greater sleep disturbance (Murdock, 2013; Thomee, Dellve, Harenstam, & Hagberg, 2010; Thomee, Eklof, Gustafsson, Nilsson, & Hagberg, 2007). In the last two decades, “worldwide mobile phone subscriptions have grown from 12.4 million to over 5.6 billion, penetrating about 70% of the global population ... on 31 May 2011 the World Health Organization confirmed that cell phone use indeed represents a health menace” (Acharya, Acharya, & Waghrey, 2013, p. 1).

**Laptops and Computers**

Figueiro, Wood, Plitnick, and Rea (2011) examined the effects of self-luminous computer devices on melatonin from twenty-one participants (aged 19-37). Subjects were tested under three test conditions: (1) computer monitor only; (2) computer monitor viewed through goggles providing 40lux of short-blue wavelength (≈ 470nm) LED light at the cornea; & (3) computer monitor viewed through orange-tinted safety glasses (optical radiation <525nm) (p. 158). Saliva samples were collected from subjects at 23:00, before starting computer tasks, and again at midnight and 01:00 while performing
computer tasks under all three conditions. Melatonin levels were significantly reduced from blue-light goggles. Daysimeter headbands were worn by participants, which is a personal circadian and photopic light exposure meter used to accurately measure subjects’ light exposure from computers. Despite the fixed regulation of computer light projected onto subjects’ corneas, a much greater level was recorded (Figueiro, Wood, Plitnick, & Rea, p. 115). Cajochen et al. (2011) found similar results that an LED-backlit computer screen emitted “3.32 times more light in the blue range between 440 and 470nm than non-LED screens” (p. 1436). Cajochen et al. (2011) also found that LED-backlight screens engaged attention, enhanced working memory, and improved declarative memory and cognitive performance on various computer tasks. Although this is beneficial for tasks requiring attentiveness and awareness to detail, the resulting effects of inappropriately-timed LED exposure will produce circadian modifications and sleep difficulties (Cajochen et al., 2011, p. 1432).

**Tablets**

Between April 2012 and May 2013, tablet ownership nearly doubled from 20% to 34% for 18 to 29 year olds. One-third of American adults (18 years and older) own a tablet, such as an Apple iPad, Samsung Galaxy tab, Google Nexus, or Kindle Fire (Zickuhr, 2013). The Pew Research Center (2013) gathered information on a sample of 2,252 adults (18 years and older) and found that between the ages of 18-24 (n = 243), 33% owned a tablet, and between the ages of 25-34 (n = 284), 37% owned a tablet. Zhang, Tillman, and An (2017) explained within their study that Flurry—a mobile analytics company—tracked data on 44,295 iOS devices during May 2013, and found the greatest usage of iPhones and iPads occurred immediately before bedtime between 8 p.m.
to 10 p.m. for children and adolescents (p. 249), and a considerable amount of activity continued to persist from midnight until 8 a.m. (Zhang et al., 2017). The advantage of children still living at home is that greater restrictions and regulations can still be implemented as an advantageous solution to the problem of after bedtime usage of tablets and other technological devices that prolong sleep; however, this living situation is not as realistic for college students because there is no longer an authoritative parental figure to impose this resolution for change.

The usefulness of tablets is becoming harder to dispute especially among members of the academic community. Tablets continue to grow as a staple within the education system. These innovative tools enable schools to keep pace with the installment of technological advances as a mechanism to further enhance the student’s learning process (Jabr, 2013). The use of e-books on tablets within the classroom has been praised for providing convenience, greater teacher-student and peer-to-peer communication, reduced educational resource costs, greater educational support, advanced literacy, cognitive stimulation, and environmental consciousness (Mayes, Sims, & Koonce, 2001). Jesse (2014) gathered data on college students (n=370) from two large universities in Pennsylvania and found that “37% of college students express that e-textbooks and e-books have a positive effect on their educational learning…73% of college students feel tablets are valuable for education purposes…36% prefer using an e-textbook on their tablet instead of a physical textbook” (p. 241). This study also found that “47% of college students feel tablets help them study more efficiently,” and “40% of college students believe tablets help them perform better in classes” (Jesse, 2014, p. 241). This trend is slowly becoming more prevalent throughout society as well. For example,
BiblioTech, a $2.3 million-dollar bookless library, opened in San Antonio, Texas in September 2013. This library, the first of its kind, offers iMacs and iPads for customers to check out up to 5 books at a time on each device (Jesse, 2014).

The use of e-books, documents, and lesson material on tablets within the classroom may also be perceived as beneficial because of the high resolution visual clarity, zoom capabilities, and user-friendly functions (e.g., touch-screen applications and easily searchable key words). However, research continues to demonstrate that paper-based work maintains an advantage because it supports greater mastery learning, recall of material, and better reading comprehension over LED tablets (Jabr, 2013; Jesse, 2014).

Noyes and Garland (2003) conducted a study comparing reading comprehension, speed, and recall with a group of 50 college participants of similar academic standing. Participants were placed into two groups: reading a document on a visual display screen or a spiral bound notebook. A total of 20 minutes was given to read the material. Once finished, participants answered 20 multiple-choice questions about whether they knew or remembered the material. Then, participants were tested on their rate of speed to read the text while still trying to comprehend the material. The researchers found no difference between the groups rate of reading speed; however, the paper group had higher frequencies for both knowing and remembering the material, while the computer group had higher frequencies for just remembering the material in the short-term (Noyes & Garland, 2003). Noyes and Garland (2003) expressed that to fully understand how screens affect our cognitive processing, “it is important that research moves away from comparing visual display terminals (i.e., screens) and paper using only superficial measures such as reading times and comprehension scores to assess the real differences
between the two media” (p. 421). This concern of needing more valid measurements to exam screens and paper was examined by Ackerman and Goldsmith (2011) who found that when students were allotted greater self-regulation over their study time as opposed to a fixed duration, metacognition (e.g., choice of study strategy, allocation and prioritization of study time, decision of when one has sufficiently mastered the material) was the primary difference between screen and paper study groups. The use of paper-based learning continues to result in more self-assessed proficiency and acquisition of knowledge regardless of applied external variables or conditions.

Wood, Rea, Plitnick, and Figueiro (2013) conducted a study on the significance of light exposure from self-luminous tablet displays on thirteen subjects (aged 13-24) years. Subjects were tested on all three experimental conditions: (1) tablets-only set to the highest brightness; (2) tablets viewed through clear-lens goggles equipped with blue light-emitting diodes that provided 40lux of 470-nm light at the cornea; & (3) tablets viewed through orange-tinted glasses (dark control; optical radiation <525 nm ≈ 0) (p. 237). Each iPad was set to full brightness delivering 40 lux at the cornea. LED displays (1024 x 728 pixels; 132 pixels/inch) were approximately 9.7 inches from subjects’ faces, while all-white tablet screens were positioned 10 inches from subject faces. During testing, subjects wore daysimeter (~2cm diameter) headband instruments that continuously recorded light spectrum colors and activity levels every 30 seconds. Subjects also maintained a regular sleep schedule, going to bed no later than 23:00 and waking up no later than 7:30. Subjects engaged in their preferred nightly tasks (e.g., games, on-line shopping, reading) to imitate typical usage activity. The results showed that melatonin suppression was present after only one hour of viewing tablets with blue
light, whereas there was no statistical significance in melatonin suppression from use of tablets only (i.e., white light) until at least two hours of viewing had occurred. Although the type of task engagement will influence light intensity, researchers found significant effects in less than one hour of use from LED tablets; therefore, regardless of technological advances (e.g., organic light emitting diodes) with more desirable lighting, “as long as the spectral irradiance distribution at the cornea from self-luminous technology is known, one can predict its impact on melatonin suppression after one hour of viewing” (Wood, Rea, Plitnick, & Figueiro, p. 240).

**Television**

A heavily researched technology device disrupting bedtime is television viewing. A plethora of research exists on this topic because television was a primary form of technology created for viewing purposes (Comstock, Lindsey, & Freemon, 1975). However, exploration regarding the effects of television viewing on the college population is less prevalent, likely because more recently there is a greater interest in the more innovative LED technological devices. College students’ independent lifestyles do not allow for imposed structured leisure activities (i.e., end times), unlike younger children who live at home and have parental guardians to implement greater control.

Asaoka, Fukuda, Tsutsui, and Yamazaki (2007) found a causal relationship between TV viewing and sleep-wake patterns among eight university students (19-21 years old) and eight elderly (70-78 years old) participants. The study lasted two weeks. During the first week, participants were asked to follow their regular routines; however, during the second week, participants’ TV viewing was limited to only 30 minutes per day. For the elderly, daily TV viewing decreased from 321.9 minutes to 15.6 minutes in
the second week, with no significant effect on their sleep-wake pattern from TV restriction. Conversely, university students’ daily TV viewing decreased from 195.0 minutes to 14.2 minutes in the second week, resulting in earlier bed times and longer night-time sleep periods. Harada, Kadowaki, Shinomiya, & Takeuchi (2004) found a similar correlation with watching late night TV and delayed bedtime/rise time among Japanese physical therapy and nursing students. Students who watched late night TV for 2-4 hours past 23:00 hours were significantly more “evening-typed” and more likely to watch TV more frequently in the week than those who watched programs for 30 minutes to 1.5 hours past 23:00 hours.

Johnson, Cohen, Kasen, First, and Brook (2004) conducted a longitudinal study from 1975 to 1993 of 759 mothers and their offspring to examine any effects from extensive television viewing during adolescence that might contribute to the development of sleep problems (psychological, physiological, or biological) by early adulthood. The mean age of offspring was 6 years old in 1975, 14 years old in 1983, 16 years old in 1985-1986, and 22 years old in 1991-1993. Interviews and questionnaires were administered to both mothers and their offspring to increase the validity and reliability of any psychiatric diagnoses that children or adolescents may have developed. Findings revealed that at age 14 years old (32.3%), 16 years old (28.6%), and 22 years old (30.3%), American children and adolescents were watching three or more hours of television per day (Johnson et al., 2004, p. 565) and an average of 21-hours per week (Gentile et al., 2004). Covariates were found to be positively associated with television viewing, even with the control of offspring age, sex, previous sleep problems, and psychiatric disorders, and parental neglect, educational level, annual income, and
psychiatric symptoms. The covariates found included frequent difficulty falling asleep, frequent nighttime awakening with difficulty going back to sleep, frequent failure to get enough sleep, usual irritability on awakening, and any frequent sleep problem. However, among all the covariates, the frequent difficulty of falling asleep (14 years = 34.3%; 16 years = 24.4%; 22 years = 26.9%), and any frequent sleep problems (14 years = 74.3%; 16 years = 42.7%; 22 years = 42.1%) were found to be most prevalent among all age groups, and continued to increase as the extent of television viewing increased. Interestingly, when young adolescents reduced the amount of time spent watching television to less than one hour per day by mid-adolescence, they experienced a tremendous reduction in the risk for succeeding sleep problems in later adolescence or early adulthood.

The American Academy of Pediatrics recommends that youth should have two hours or less of sedentary screen time per day and one and a half hours of watching TV was a risk for in children (aged 4-9 years old) (Hill et al., 2016, p. 2), because anything more than “two to three hours of media time” (Gentile et al., 2004, p. 1236) can equate to violent behavior that persists into adulthood, such as high-risk actions (e.g. substance abuse, sexual activity), less physical activity, increased obesity, decreased reading, reduction of interaction with peers, increased hostile behavior, and mental health outcomes (Calamaro, Mason, & Ratcliffe, 2009).

Technological devices have progressively become a necessity among and within society. Despite their convenience and practicality, existing research explains the ways in which these devices are negatively impacting health, physiology, psychological stability, academic progress, and sleep. Among the items listed, sleep is a controllable and
fundamental requirement for better focus, attention, and information retention. Therefore, the discussion how sleep and sleep deprivation are important aspects for academic achievement among college students will be further discussed.

**Sleep Deprivation**

Sleep deprivation is defined as “obtaining inadequate sleep to support adequate daytime alertness” (Hershner & Chervin, 2014, p. 74). It is estimated that roughly “50-70 million Americans have a chronic sleep disorder” (“Sleep and Sleep Disorder Statistics,” 2017) that associates with “depressed mood, difficulty concentrating, drowsiness, impaired memory and impaired cardiovascular, endocrine, immune, interpersonal, occupational, psychomotor, and metabolic functioning” (Johnson et al., 2004, p. 567). College students are still dealing with the biologically driven factors that delay sleep onset that started in adolescence, in addition to newfound social influences (e.g., noisy residence halls or apartments) that also disrupt sleep patterns.

The consequences of sleep deprivation for college students, whether acute or chronic sleep deprivation, can lead to serious implications with associations to decreased sleep duration, delayed bedtime and wake time, unbalanced sleep/wake patterns, disrupted sleep quality, and impairments to school performance (Wolfson & Carskadon, 2003). Engle-Friedman et al. (2003) wanted to determine two objectives: a) if sleep loss for undergraduates results in a preference for tasks that require minimal effort (n=18 males; n=32 females; ~19 years old); and b) if participants’ quality of performance under conditions of sleep loss was affected despite having control over task demands (n=22 males; n=36 females; ~18 years old). In both experiments, there was a single-night sleep-
deprived group and a control group. For evaluation of sleep impact, participants from both experiments were asked to complete a math effort task of addition problems on the computer. In both experiments participants who were sleep deprived selected less difficult and less demanding (i.e., non-academic) tasks, which was a result of increased sleepiness, more fatigue, and longer reaction times. Interestingly, sleep deprived participants did not perceive a reduction in effort levels though their performance showed otherwise. In fact, sleep deprived participants reported equivalent effort expenditures as the non-sleep-deprived control groups (Engle-Friedman et al., 2003). Hockey, Wastell, and Sauer (1998) aided in this finding by expressing that due to the constraints and limitations of sleep-induced stress, the neuro-correlates of the brain become forced to selectively attune high levels of effort with limited resources as a task approach strategy to try and return to a state of equilibrium. This supports sleep deprived participants’ choice for less demanding tasks because they are more certain their level of attention can match the level of difficulty to maintain a degree of advantage and success.

Sleepiness has been shown to be one of the most significant predictors affecting academic achievement and school performance (Dewald-Kaufmann, Meijer, Oort, & Bogels, 2010). A single night of sleep loss can induce events of micro-sleeps which have been associated with poor school performance and achievement, and if ongoing, lead to excessive daytime sleepiness (Millman, 2005; Gibson et al., 2006). Micro-sleeps are “brief (0.5-15s) episodes of complete failure to respond, accompanied by slow eyelid-closure – and EEG theta activity during drowsiness in a continuous task” (Poudel, Innes, Bones, Watts, & Jones, 2014, p. 257). Micro-sleeps are “very short periods of sleep-like-electro-encephalography (EEG) activity” (Alhola & Polo-Kantola, 2007, p. 554) that
arise from drowsiness and result in numerous incidences of a momentary loss in awareness throughout the day. Constant eye-closing, blank stares, and nodding-off are physical indications of micro-sleeps, but mental deficits become more apparent during continuous tasks (Boyle, Tippin, Paul, & Rizzo, 2008), selective attention tasks, and short-term attentional tasks (Poudel et al., 2014).

Micro-sleeps are a physiological response of the body’s persistent desire for sleep. This transitional state between wakefulness and brief sleep episodes results from fluctuations of the brain’s neurochemicals fighting alertness (i.e., adenosine) and sleep onset (i.e., dopamine), which enhances pontine-geniculate-occipital waves (electrical impulsive waves) that are highly present during REM sleep (Silkis, 2010). This constant state of oscillation interferes with higher cerebral functioning (e.g., decision making), attention (i.e., vigilance), divergent thinking, creativity, language (Alhola & Polo-Kantola, 2007), and poor visual processing ability, and impairs “short-term memory, concentration, cognition, and intellectual performance” (Lemma, Berhane, Worku, Gelaye, & Williams, 2015, p. 262).

**REM Sleep**

REM sleep is enigmatic and fascinating because it contains coinciding aspects of both deep sleep and wakefulness. Dahl and Lewin (2002) explain:

REM appears deep because the changes in the body (loss of muscle tone) and subcortical brain systems, such as temperature regulation and control of respiration and heart rate, are more profound than in any other stage of sleep. On the other hand, higher cortical brain functions are quite active and resemble wakefulness. (p. 176)
This highly specialized sleep state is uniquely different from Non-REM sleep stages because it contains dreams and because of the significant contribution that REM sleep plays in sleep-dependent learning and memory consolidation. REM sleep is the brain’s mechanism for organizing everyday experiences to either retrieve or relieve information, facilitate learning, and reconsolidate those experiences into long-term memories (procedural or declarative) (Maurizi, 1987). It should be noted, however, that there is more than one type of memory. These memory systems “store different classes of memory in different brain regions…after the initial encoding of the sensorimotor experience, a series of cellular, molecular, and systems-level alterations…stabilize and enhance the initial memory representation, converting it into a long-lasting and optimally integrated memory” (Stickgold, 2005, p. 1272). It is the integrated, additional components of the memory-consolidation process through REM sleep that provides the greatest support for sleep dependency.

A key task of REM sleep involves the brain processing information from the previous day by establishing or strengthening neuron connections of that which was recently learned. During REM sleep, the brain reenacts the previous day’s events to refine and reform learning through repetition, which improves the memories, making those learned tasks more useful in the future so performance of the task or information processing continues to improve (Blumberg, 2010; Stickgold, 2005). fMRI and EEG studies have found that brain wave activity during REM dreams appears almost indistinguishable to that during the actual event, as if the tasks are being performed while dreaming (Dresler et al., 2011; 2012).
During visual discrimination (Stickgold, Whidbee, Schirmer, Patel, & Hobson, 2000) and motor sequence tasks (Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002), the amount of sleep that subjects obtained during the intervening night, as opposed to the amount of sleep received prior to training or the time interval between training and testing, was critical to task improvement. More specifically, no significant improvement was observed in either the visual or motor tasks unless participants had at least 6 hours of sleep between testing and re-testing. Walker et al. (2002) found that a night of sleep resulted in a 20% increase in motor speed without any loss of accuracy, while the same duration of time spent awake did not provide any additional benefits to participants. Stickgold et al. (2000), dividing the night into four quartiles, found that participant task improvement was strongly dependent on increased REM sleep. Participants’ maximum level of learning increased substantially after the last quartile of the night, when the REM sleep cycle is longest. That during task training, improved performance appears to occur during slow-wave sleep (non-REM) and REM sleep, with more complex tasks being strongly dependent on REM sleep (p. 251). REM sleep also “fosters the integration of neocortical memories into wider associative networks…serving both declarative/episodic and procedural/implicit memories…in terms of strengthening existing memory traces” (Stickgold, 1998, p. 491).

Brief 60-90 minute naps that contain both slow-wave sleep (non-REM) and REM sleep have been shown to enrich the magnitude of learning that develops over 24 hours of sleep. Mednick, Nakayama, & Stickgold (2003) tested whether slow-wave sleep (non-REM) naps without REM sleep were necessary for learning. Results found that 60-90 minute naps with slow-wave sleep but without REM sleep produced no improvement on
the task; however, both slow-wave sleep and REM sleep produced significant improvements. More precisely, subjects were tested at 9:00, napped for 60-90 minutes at 14:00, and were re-tested at 19:00. When subjects were re-tested the next morning on day 2, the 90-min nap group showed an additional 9.7 ms of improvement; whereas the no-nap group showed deterioration of speed and accuracy at 19:00 and no significant improvement on day 2. Overall, findings portrayed that naps can show improved performance on discrimination tasks similar to the level of reported learning after a full night of sleep (Mednick, Nakayama, & Stickgold, 2003, p. 698).

**Light Emitting Diodes**

Insomnia has been shown to be related to a hyper-aroused state that is a result of environmental, social, or psychological stimuli and not necessarily just circadian rhythm fluctuations. “Secondary symptoms of insomnia (e.g., fatigue, cognitive impairment, and general dysphoria) are not due to loss of sleep per se, but may be better explained instead by persistent hyper-arousal” (Lack, Gradisar, Someren, Wright, & Lushington, 2008, p. 311).

Technological devices are now primarily being manufactured with LED light, which is within the peak wavelength on the color spectrum of blue-green (~460nm). This wavelength is primarily responsible for responses like “resetting the timing of the circadian pacemaker, suppressing melatonin production, improving alertness and performance, and elevating brain activation” (Cajochen et al., 2011, p. 1432). Furthermore, blue light exposure prolongs sleep and reduces “initial EEG delta activity, a marker of slow-wave sleep” (p. 1432). During the evening, before bedtime, is when our circadian rhythms are most susceptible to light and therefore, most vulnerable to rhythm
modifications. Figuiero et al. (2006) found that only a 30lux dose of incandescent light directed at the cornea for just 30 minutes is needed to generate a degree of melatonin suppression. However, the greater amount of short-wavelength light emitted from a white light source (e.g., daylight, tablet, computer, smartphone) rather than incandescent light will only further enhance the intensity of melatonin suppression (Figuiero, Wood, Plitnick, & Rea, 2011, p. 114).

**Melatonin suppression.** Melatonin is a chemical hormone produced in the pineal gland, located within the limbic system and basal ganglia, that is released during conditions of darkness to induce sleep (Wood, Rea, Plitnick, & Figueiro, 2013). Melatonin secretion begins to rise approximately two to three hours before regular bedtime and is strongly influenced by internal (e.g., body temperature), physiological (e.g., wake-maintenance zones), and external (e.g., light) factors (Figueiro & Overington, 2016).

Sleep is most favorable when body temperature is at a minimum phase in the sleep/wake cycle while melatonin and sleep propensity are at their highest point. Lack, Gradisar, Van Someren, Wright, and Lushington (2008) explained that temperature minimum usually occurs between “04:00 and 06:00,” (p. 308) and “sleep is typically initiated on the falling limb of the temperature rhythm about 5-6h before the core body temperature (CBTmin) minimum, with maximum circadian sleepiness occurring at the CBTmin...habitual wake up time usually occurs about 1-3h after CBTmin” (Lack et al., 2008, p. 308) as core body temperature increases.

This process is called thermoregulation, and is adjusted by the body’s core (i.e. central nervous system) and shell (i.e. peripheral nervous system) temperature systems.
that both adjust the body’s heat levels to ensure homeostasis prevails during our 24-hour sleep/wake cycles. The brain is the primary facilitator of the body’s core temperature system, with the suprachiasmatic nucleus as a principal initiator in the regulation process. However, a wake-maintenance zone (Lack et al., 2008, p. 308) also exists as a considerable factor that is strongly influential to sleep onset. This zone “occurs in the early evening, about 6-9h before the CBTmin and 1-4h before habitual bedtime (18:00-22:00)” (Lack et al., 2008, p. 308). While in the wake-maintenance zone, body temperature and external factors (i.e., light) will have a substantial impact on circadian phase shifts, dim light melatonin onset (DLMO), and increased levels of insomnia because sleep onset can be easily delayed during this period.

Circadian phase delay occurs when the light stimulus is applied before the midpoint of melatonin secretion or minimum core body temperature. Conversely, light exposure applied a few hours after the sleep/wake phase melatonin response and minimum core body temperature will produce circadian-phase advances. This reiterates that phase delay or phase advancement resetting are both possible, depending on the level of light intensity applied (Khalsa, Jewett, Cajochen, & Czeisler, 2003, p. 950; Figueiro & Overington, 2016, p. 966) along with timing and duration of the stimulus.

Melatonin is the primary hormone that prompts sleep. Therefore, it is imperative to understand a few factors that contribute to the suppression of melatonin during bedtime hours, which lead to sleep delay and circadian rhythm shifts thereafter. Specifically, if the suprachiasmatic nucleus is activated from LED light stimulation during a sensitive pre-sleep period (i.e., wake-maintenance zone), it will not only
suppress melatonin but also raise body temperature, which both are pivotal factors necessary to promote sleep.

Sleep is multi-faceted in the ways that it contributes to alertness, focus, learning, and information retention. As explained, biological and physiological factors are already influential on sleep. Introducing a highly powerful external factor, such as LED light during peak hours of transition between alertness and drowsiness, can substantially alter sleep patterns for college students. Understanding the severity of sleep and the neurological underpinnings of sleep on learning gives more substance to its importance. Next, the aspects of how learning and academic achievement is affected by sleep will be explored.

**Academic Achievement**

It is known that learning acquisition and memory processing are necessary to enhance academic achievement and school performance (Curcio, Ferrara, & Gennaro, 2006). Sleep is also an integral part of that practice that aids in the repair and growth of restorative procedures that coincide with learning and memory consolidation. Sleep is a very “active process wherein some brain regions show the same (or increased) activity during wakefulness…there are several aspects of sleep including the continuity, timing, and patterning of different stages of sleep that are necessary for the restorative process to occur” (Dahl & Lewin, 2002, p. 175). Considering the neurocognitive, physiological, and psychomotor performance factors that are heavily dependent on sleep, it is concerning that sleep loss is quickly sacrificed among adolescents and college students who need it the most at this stage in development (Benington, 2000).
The onset of puberty in early adolescence brings forth a natural delay of sleep timing and a shift of homeostatic regulations throughout the body’s entire circadian rhythmic processes (Curcio, Ferrara, & Gennaro, 2006). During adolescence, it is normal for external factors, such as academic, familial, social, and environmental pressures, to facilitate stress and sleep loss; however, it is the internal stresses that significantly impact stability and modulation. Changes to brain maturation during this time affect the formation of neural connections and neuron pruning, hormonal balance, emotion regulation, and higher executive rationale (Colrain & Baker, 2011). Among all the fluctuations, the one most significantly affected is sleep. It is during this stage of developmental maturation that sleep becomes particularly important to learning, memory acquisition, consolidation, and recall (Dahl & Lewin, 2002).

At birth, the human brain contains an influx of neurons that progressively prune away during the first two years of life (Colrain & Baker, 2011). This process allows the residual neurons to become more specialized on pertinent information that is vital to survival, simultaneously strengthening the remaining neural connections. The period of adolescence and early adulthood, which is defined as “the period between the onset of puberty and the acquisition of sexual maturity and adulthood” (Colrain & Baker, 2011, p. 6), is the second most important time in development of brain restructuring, reorganization, and significant alterations. In this phase, neural EEG power is marked by significantly slower delta (deep sleep) wavelength frequencies. This evidence suggests that total REM sleep is related to the underlying changes in adolescent and adult brain reorganization (Tarokh & Carksadon, 2010), which also explains the need for longer sleep duration.
Circadian cycle shifts beginning in adolescence lead to later bedtimes and rise times, which initiate the onset of daytime sleepiness for teens and young adults (Dahl & Lewin, 2002, p. 178). Evening-preferred chronotype individuals are defined as those with a “temporal preference which characterize individuals as nocturnal or ‘owls’” (Golombek & Cardinali, 2008, p. 1). Evening-preferred chronotype individuals experience the greatest amount of daytime sleepiness (Gibson et al., 2006), later bedtimes and wake-up times, shorter time in bed during the week, longer weekend time in bed, irregular sleep-wake schedules, increased naps during school days, more attention problems, poor school achievement, and more emotional turmoil than morning chronotypes (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002). During grade school and high school, school start times are fixed, which may assist in less reported adolescent sleep dissatisfaction. K-12 student schedules are drastically different from the independent lifestyles of college students who can create their own schedules to accommodate their diverse sleeping patterns. Regardless, beginning at approximately 20 years old, sleep disturbances (e.g. sleep latency, nocturnal awakenings, and sleep quality) begin to arise and insufficient sleep schedules only further serve to intensify this problem.

Samkoff and Jacques (1991) found that acute sleep deprivation for medical residents led to significant deterioration of mental alertness on performance tests and procedural tasks that required perceptual awareness and attention, which parallels some of the rigorous demands during an academic term for college and graduate students. Findings also revealed that acuity, reaction times, and short-term recall were not adversely affected by sleep loss, but this increased root memorization, short-term
performance-based goals, episodic memory, procedural learning, and an absence in retaining long-term knowledge (Curcio, Ferrara, & Gennaro, 2006).

Tiredness is “the feeling of fatigue that makes it difficult to motivate or initiate certain types of behavior, particularly those behaviors associated with long-term goals or negative consequences” (Dahl & Lewin, 2002, p. 175). This common form of fatigue (lethargy) may cause more problems with memory, focus, and concentration than pure sleepiness (struggling to stay awake) (Alapin et al., 2000). Zammit (1988) believed that cognitive inefficiency in performance and exhaustion would emerge as single dimensions, but found that they were congruent components of a single dimension that sleepiness and poor cognitive performance are strongly associated (p. 125) and also, strongly associated with most other subscales in the study: dysphoria (lack of energy, social withdraw, low interest and inattentiveness), motor impairment (clumsiness, accident prone, and poor voluntary control), and social discomfort (depression, inadequate, and general feelings of discomfort). This is interesting because even just feeling tired or fatigued can substantially hinder college students’ ability to evoke drive towards a plan, achieve objectives, or process the negative outcome(s) of not achieving academic success.

The information from this research study should provide greater awareness for the college population regarding the significant affects that result from sleep deprivation on learning, motivation, memory consolidation, neuron formations, and academic success. Because this period of development requires a significant amount of sleep when academics are the most challenging, further understanding of any disruptions or influences that affect this progress should be explored.
Below is a concept map that provides a visual depiction of the topics previously discussed that better represents the relationship between academic achievement, sleep deprivation, and the types of LED technology being used before bedtime.

Figure 1. Concept map of literature review topics.
Conclusion

The literature shows that adequate sleep is vital to college students’ neural connectivity, memory consolidation, academic performance, mental stability, and mood regulation, but the direct effects on academic achievement and learning are still understudied. More studies that explore students’ drive, attention, focus, intrinsic motivation, and approach toward pursuing their academic goals will support the need for greater research that illuminates how sleep deprivation is directly related to academic achievement.

Additionally, the previous research illustrates that pre-sleep usage of LED technology delays sleep onset for the college population, but the indirect effects this has on academic achievement and school success is still understudied. More research that explores greater detail about the timing, duration, intensity, and proximity these devices have on sleep delay for students will provide greater demand for studies that clarify research findings about how LED technology affects academic success, mastery learning, and academic achievement.

Finally, discussion of how the usage of pre-sleep LED technological devices delays sleep by re-awakening the brain through the suprachiasmatic nucleus from light stimulation, suppressing melatonin, and shifting the circadian rhythm, but the specific effects that each individual device has on sleep delay is still lacking. More research that explores greater detail about the duration of time spent on each device, intensity of light, proximity to bedtime usage, and number of times sleep is interrupted from these devices will provide a greater need for studies that clarify research findings about how this affects sleep quality and sleep duration.
Theoretical Framework

This study explores the relationship between usage of light-emitting diode [LED] technology prior to bedtime and its influence on sleep behavior and academic achievement pertaining specifically to college students. Although prior research on this population has separately focused on the relationship between LED light technology and sleep and/or the relationship between sleeping behavior and academic success, to date, no research has focused on the relationships between all three facets. This is noteworthy for several reasons. First, college is a very demanding time that requires considerable concentration and focus, especially because academics are very arduous at this stage. Simultaneously, this transitional phase between adolescence and adulthood is when students are no longer faced with parental control and therefore experience an abundant level of independence. This freedom allows students greater autonomy with their choices in relation to their degree of academic engagement, sleep schedules, and pre-sleep activities, particularly with regards to the usage and duration of LED technology. These considerations emphasize the need for additional research findings to better understand how to continually improve academic success at this level.

This section will discuss the measurement scales that best examine the relationship between pre-sleep LED technology use and the effects on sleep patterns and academic achievement. This will be further expanded upon by starting with a discussion of sleep as it is the single connecting variable explored in this study between LED light technology usage prior to bed and academic achievement. Then, the tools to measure academic achievement will be explored.
First, to measure sleep, the Epworth sleepiness scale has been selected. This scale contains components of various daily situations that enhance sleepiness that will lead further into the discussion of excessive daytime sleepiness and other related sleep disorders commonly experienced by the college population. This accentuates the importance of sleep quality and how external influences, like LED technology, can significantly affect sleep onset and sleep duration. Finally, the correlation between sleep and learning will be explained, setting the foundation for the last variable to be discussed, academic achievement.

Then, to measure academic achievement, the subsequent section will explore the components that comprise the two measurement scales used in this study: the motivated strategies for learning questionnaire (MSLQ) and the 3x2 achievement goal framework. The breakdown of each concept within the measurement scales will provide more clarification about the connection between sleep, learning, and academic success. It is important to note that although evaluating academic performance with regards to GPA and test scores are certainly easier constructs to use when assessing whether sleep debt is affecting college students’ academic learning and success, such a focus would only further support an already biased perception within the educational system that performance equates to success. The level of mastery learning required for expertise in a subject area may vary in both definition and overall interpretation; however, most can agree that mastery learning may be perceived as accumulated learning or knowledge over time from continuous pursuit for acquisition of novel information in various subjects. This objective stance supports academic achievement which is rooted in aiding students to develop an intrinsic drive towards their academic career and remain persistent over the
long-term seems more beneficial rather than emphasizing the importance of competition or standards for short-term gains.

Thus, mastery learning, not performance, will be explored within this study as a measurement of academic success. This decision supports the desire for greater encouragement of intrinsic drive as opposed to external rewards and/or incentives for academic in academics. Mastery learning accomplishes this objective through instructional techniques and step-process learning levels that students must attain before moving forward. Consequently, greater understanding of the material is achieved as opposed to memorization. Cognitive learning strategies are incorporated into this teaching style for organizational and structural purposes, while also providing students greater resources to use in the future (Alexander, Graham, & Harris, 1998).

Sleep

Excessive sleepiness is a “readily reversible state of reduced responsiveness to, and interaction with, the environment” (Bear, Connors, & Paradiso, 2007, p. 594). The more popular sleep measurement scales assess sleepiness as either “sleep propensity or a state of drowsiness” (Johns, 2010, p. 171) typically in a lab setting and do not account for how sleep propensity changes throughout each daily situation. Having a brief understanding of these related well-known scales, will aid in the significance and originality of the Epworth sleepiness scale.

Sleepiness Scales

The first scale to be considered is the multiple sleep latency test (Carskadon & Dement, 1977; Carskadon, Dement, & Mitler, 1986). This scale currently remains one of
the most widely used methods for measuring sleepiness (Johns, 1993; 2010). This scale assesses sleep according to its state of existence along with its intensity level. Tests are typically conducted in a stationary laboratory setting, and evaluates the ease of sleep disruption, the total duration of hours slept, and how quickly sleep onset arises. This scale “establishes a setting to maximize the likelihood of sleep onset,” while “all factors competing with falling asleep are removed from the test situation” (Johns, 1993, p. 31). Simply put, this scale evaluates sleep latency by having participants take four to six half-hour naps, at least two hours apart during the day, ultimately trying to measure a participant’s ability to fall asleep during a single event (Carskadon & Dement, 1979; Carskadon, Dement, & Mitler, 1986; Johns, 1993).

The next scale being considered is the maintenance of wakefulness test (Mitler, Gujavarty, & Browman, 1982), which is perceived as a variation of the multiple sleep latency test. This test also focuses on sleep latency by asking participants to stay awake and alert while sitting idly in a dimly lit room for forty minutes, again measuring participants’ ability to stay awake in a stationary laboratory setting (Johns, 1993).

The final scale being examined is the Stanford sleepiness scale (Hoddes, Zarcone, & Dement, 1972). This measurement identifies sleepiness to be a state of “feeling tired or fatigued and the subjective changes that immediately precede sleep onset, which is called ‘subjective’ sleepiness” (Johns, 1993, p. 30). During the behavioral scale evaluation portion, participants assess their subjective perceptions regarding their current state of alertness, or lack thereof. Consequently, the less alert an individual becomes, the greater their state of daydreaming or inattention becomes.
These commonly used sleepiness scales appear to be usable for this study, however, they do not account for the subjective sleep propensity variation of daytime sleepiness on each situational context along with the intrinsic and extrinsic aspects influencing voluntary and involuntary sleep drive. Understanding the origin of the Epworth sleepiness scale along with its justification and usefulness is essential, because it not only assesses factors affecting daytime sleepiness but may also be used as a guide for diagnosing other-related sleep disorders. Consequently, the Epworth sleepiness scale will be most useful for this study because it takes into consideration both internal and external characteristics of sleep-wake drives that affect daytime sleepiness.

**Epworth Sleepiness Scale**

The Epworth Sleepiness Scale, broadly speaking, was introduced in 1990 by Dr. Murray Johns for his private practice sleep medicine patients. His questionnaire was named after the Epworth hospital in Melbourne, Australia where he established the Epworth Sleep Centre in 1988. The scale was intended to measure an individual’s level of daytime sleepiness and/or the average tendency to experience sleepiness as an individual confronts daily activities. The primary objective of the Epworth Sleepiness Scale is to emphasize that sleepiness is not a characteristic that can be measured independent of a situation, nor can sleepiness be applicable to all people or all life situations. Rather, the scale tries to differentiate between daily activities that stimulate sleepiness as opposed to general feelings of fatigue or drowsiness from concerted or consistent effort (Johns, 2010). The Epworth sleepiness scale has been specifically chosen for this study with the objective that it will provide greater understanding of the various circumstances in which college students are experiencing excessive daytime
sleepiness. Then, taking this information in conjunction with their sleeping behaviors and pre-sleep LED screen-time usage should provide a more holistic perspective of some relevant factors affecting college students’ academic achievement.

To date, the Epworth sleepiness scale is one of the most commonly used methods to measure an individual’s sleep propensity or inclination, which Johns (2010) explains is different from general sleepiness or sleep latency. Traditional sleep models typically measure an individual’s sleepiness or drowsiness by assessing the transitional phase between complete alertness to a state of complete sleep, and is usually measured in a lab environment and/or other non-real life setting(s). John’s model is unique because it further separates wake drive into two components: primary and secondary.

The primary wake drive, like most sleep models, pertains to activity within the suprachiasmatic nucleus that reacts to our circadian rhythms. The secondary wake drive, however, relates to exteroceptive inputs from the environment (e.g., visual cues, light stimulation, noise level, temperature) and enteroceptive sensory inputs between the cerebral cortex and central nervous system (e.g. nerve impulses, muscle/joint reactions, mental activation, phasic activity, vestibular input from the ears) (Johns, 2009, p. 4).

Johns (2009) conceptual model also expresses a term called sleepening, which implies that an individual can voluntarily enhance falling asleep by reducing aspects of the secondary wake drive (e.g., lying down in a dark, comfortable, quiet place, closing our eyes to block light stimulation, relaxing postural muscles, and stopping purposeful movement) (p.4). Situational sleep propensity is the probability or “speed, ease, or likelihood of falling asleep as opposed to remaining awake” (Johns, 2010, p. 171) when measured in the same situation repeatedly (e.g., watching tv in the evening, intending to
stay awake). However, excessive daytime sleepiness can be caused by numerous factors, such as high sleep-drive, low primary/secondary wake drive, or interference of the sleep drive by the wake drive and therefore, situational sleep propensity is not sufficient enough to evaluate excessive daytime sleepiness.

Johns (2002) introduced somnificity to imply that “the somnificity of each activity, with its typical posture, levels of physical and mental activity and of environmental stimulation at the time, measures the relative capacity of an activity and situation to induce drowsiness in the majority of people” (Johns, 2009, p. 5). Somnificity is not a “characteristic of individual subjects, their sleep disorders or levels of sleepiness. It measures the effects that particular activities have on the secondary wake-drive in the majority of people” (Johns, 2009, p. 5; Johns 2010). The situation and/or environment also needs to be considered when evaluating for sleepiness, and if sleepiness is found, it cannot be applied to all settings as it is subjective to each situation, and will change based on each individual.

In relation to this study, the environmental situations mentioned above that relate to the secondary wake drive will pertain to the total duration and quality of sleep received the previous night. The total duration of time the individual has been awake, and the subjective level of stimulation an individual associates to a particular place or setting will also be considered. Greater understanding about how these factors affect daytime sleepiness may shed light on underlying issues affecting college student’s academic achievement.

Somnificity
The first aspect of the Epworth sleepiness scale being discussed pertains to “somnificity” (Johns, 2002). Somnificity relates to aspects surrounding of our secondary wake drive, such as an individual’s perceived level of sleepiness depending on the time of day, total duration and quality of sleep from the previous night, incorporation of any naps taken, and current amount of time spent awake. Daytime sleepiness also depends on the situational contexts of people’s daily lives that either increase or decrease their sleep propensity at any given time. For example, lying down in a warm, quiet bed without voluntary movement in complete darkness for several consecutive minutes is a suggestive situation with high somnificity for some people (Johns, 2010). This example brings forth consideration as to what activities have higher somnificity for some individuals and not others. Although the previously stated external factors are relevant, such as time of day and duration of the prior night’s sleep, the internal effects to the circadian rhythm and re-awakening the brain are also influential to somnificity and must be further discussed to explore all factors possibly affecting daytime sleepiness (Johns, 2010, p. 177).

Circadian rhythms are the internal, biological “clock” that keeps a schedule with the earth’s cycle of daylight and darkness. More specifically, this is the brain’s attempt to entrain a closely related cycle to the 24-hour rhythm of daylight to darkness as an inner source of regulation (Duffy & Wright, 2005; Bernard, Gonze, Cajavec, Herzel, Kramer, 2007). This information is important to this study because despite our external choices that may promote sleep deprivation or our voluntary practices that encourage sleep debt, our circadian rhythms will ultimately maintain a consistent effort of keeping our bodies in sync with a regular sleep cycle by constantly realigning with direct sensory
environmental cues, such as lightness/darkness or temperature (Bear, Connors, & Paradiso, 2007, p. 609) to remain in sync with the sun’s 24-hour light cycle.

The portion of the brain that physically processes and conducts the entrainment of light to the 24-hour cycle is called the suprachiasmatic nucleus. This cluster of neurons is located directly above the optic chiasm, which is the location where the optic nerves from each retina intersect. Melanopsin is located within the retina, and contains highly specialized photoreceptors that are different from the well-known rods and cones. These photoreceptors can activate the suprachiasmatic nucleus due to the photopigment within melanopsin that comprises light-sensitive proteins (Bear, Connors, & Paradiso, p. 615). As the melanopsin neurons become stimulated by light (e.g., LED light technology), they communicate any sensitivity immediately to the suprachiasmatic nucleus, ultimately informing it to reset the circadian rhythm(s) and/or, at least, awaken them. Once this message is received, the suprachiasmatic nucleus then passes along this message using neuron action (i.e., movement, energy, or motion) potentials throughout the rest of the brain’s rhythmic systems (e.g., body temperature, decreased melatonin secretion, increased hormone secretion into blood stream) (Bear, Connors, & Paradiso, 2007). In short, when the suprachiasmatic nucleus within the brain is stimulated by the short-wavelength (~480nm) of blue light, it immediately alerts and awakens the entire body to wake up because this wavelength is the same as daylight.

The transferring of messages from the suprachiasmatic nucleus then wakes up the hypothalamus. The hypothalamus has many functions, one of which is to control the daily cycles of physiological states and behaviors (Bear, Connors, & Paradiso, 2007, p. 610). More specifically, the hypothalamus controls circadian rhythms by connecting the
nervous system, which coordinates actions and transmits signals, to the endocrine system (i.e., bodily glands that secrete hormones to regulate activity) through the pituitary gland. The pituitary gland allows for instant hormone secretion throughout the entire body to major organs, which either activate or deactivate bodily functions to transition the body into a complete awake state. These functions can induce physical activity, sleeping and waking, or eating and drinking (Bear, Connors, & Paradiso, 2007). Thus, activating the suprachiasmatic nucleus at times that are not in accordance with our sleep schedule disrupts the sleep cycle and disrupts the remaining body cycles that are entrained to sync with sleeping patterns.

Knowledge about external (i.e., postures/stance, activities, events) and internal (i.e., sensory and central nervous systems) aspects that influence the degree of sleep onset and our sleep schedules is significant in understanding sleep propensity and excessive daytime sleepiness. The “situational contexts” within our daily lives that Johns (2002; 2010) refers, will be explained next to understand more about sleep propensity and somnificity.

**Situational Sleep Propensity**

The second aspect of the Epworth sleepiness scale being examined is situational sleep propensity. This concept pertains to an individual’s subjective level of sleep propensity while being consistently engaged in a single, sustained activity for an extended duration of time. Although this is not a unique concept among existing sleep scales, it is new in the sense that Johns (1991) explained how each individual’s level of sleepiness when engaging in a specific activity can only be applied to that particular event, calling it *situational* sleep propensity as it can change per each new situation or
circumstance. In relation to this study, “situations” may be participating in class, lying down and reading homework, completing an online exam, or in-class group work.

Situational sleep propensity is one of the fundamental construct of the Epworth sleepiness scale because this measurement scale is essentially trying to determine an individual’s average sleep propensity by assessing an array of daily situational sleep propensity activities that are applicable to most everyone’s lives, enabling results from this study to be more generalizable to a greater population. Again, prevailing sleep scales have not taken into consideration that sleepiness not only varies according to each individual but, more importantly, varies for each person according to the event in which they are engaged. Because college students are participating in numerous activities that can influence their academic achievement, this particular scale is ideal for this study.

Unlike the general population, the college population specifically explored in this study may be at a higher risk for excessive daytime sleepiness because they are experiencing significant sleep deprivation at a point in development when they need the most sleep.

**Excessive Daytime Sleepiness**

Research findings have indicated that “over 60% of college students were poor-quality sleepers, resulting in daytime sleepiness and an increase of physical and psychological health problems…lowered quiz scores, more inattentive behavior and lower arousal” (Ahrberg, Dresler, Niedermaier, Steiger, & Genzel, 2012, p. 1618). Excessive daytime sleepiness is quite serious and in fact, it is a medical condition denoted as a sustained state of extreme sleepiness throughout the entire day, which results
in a severe lack of energy and/or fatigue due to unregulated sleep schedules/patterns, regardless if an extended duration of sleep overnight was obtained (Slater & Steier, 2012). Not surprisingly this disorder is predominantly associated with reduced attention, delayed reaction time, and impaired memory functionality (Taylor, Bramoweth, Grieser, Tatum, & Roane, 2013), which coincides with previous research findings of students with excessive daytime sleepiness. However, excessive daytime sleepiness is still a rather broad term that encompasses several specific sleep disorders and related symptoms/ailments of underlying sleep conditions (Slater & Steier, 2012); explaining all of them is outside the scope of this paper, but those most relevant to the population of this study will be discussed further to portray a more complete picture of excessive daytime sleepiness and how it impairs memory, cognition, and learning.

**Sleep Disorders**

A sleep disorder is a general term for sleeping disturbances or disruptions (Slater & Steier, 2012). A sleep disorder encompasses an array of manifestations, however, the most salient feature is the inability to fall asleep or the inability to go back to sleep once awoken during the night due to consistently re-awakening.

First, insomnia pertains to difficulty falling asleep or staying asleep for no apparent reason. Most sleep disorder problems disrupt daytime functioning, impair memory, cause depression, and increase mood swings (e.g., irritability, anxiety). Insomnia ranges from lasting a few weeks (acute) to a few months (chronic), regardless if an adequate amount of sleep is obtained (Slater & Steier, 2012).

Next, delayed sleep phase syndrome is a circadian rhythm disorder most notable for causing difficulty falling asleep and awakening at set times, along with excessive
morning sleepiness that impairs cognitive functioning. Because total sleep duration is significantly reduced, this also implies that rapid eye movement [REM] sleep is affected. REM sleep contributes to integration and consolidation of memory processing and learning; therefore, lack of REM sleep influences learning comprehension abilities (Bear, Connors, & Paradiso, 2007).

Finally, idiopathic hypersomnia is a neurological condition that causes excessive daytime sleepiness, due to neural dysregulation of sleep-wake cycles. This imbalance leads to extreme difficulty waking from a significantly deep sleep. Sleep paralysis, muscle weakness, and hallucinations may also be experienced during falling asleep or awakening (Casale et al., 2009). Theorists surmise these hallucinations result from disrupted REM sleep, a stage in which learning (i.e., memory consolidation and neural connections) is most prevalent. Those affected may experience sleep inertia, which impairs their ability to perform mental or physical tasks throughout the day due to a significantly declined physiological state of disorientation after awakening (Casale et al., 2009).

Again, these conditions are relevant because excessive daytime sleepiness may embody the symptoms similar to numerous sleeping conditions and disorders. Having greater awareness about the side effects from these sleep disorders/dysfunctions provides more understanding about the severity of excessive daytime sleepiness. Each sleeping condition/disorder consistently references disruptions to the sleep cycle; therefore, it is necessary to further explain the sleep cycle phases.

Sleep Stages
While sleeping, the brain cycles through five stages of sleep several times throughout the night, with each stage becoming progressively longer. Essentially, this is why extended durations of sleep are necessary because otherwise we cannot stay in these stages as long as needed for memory and learning processing. Stage one comprises the lightest period of sleep that is merely “transitional…and fleeting, lasting only a few minutes” (Bear, Connors & Paradiso, 2007, p. 596). Stage two is somewhat deeper, lasting for several short minutes. Additionally, this stage is when eye movements subside and spindle brain waves become apparent, which become progressively slower with periodic spurts of rapid brain waves. Stages three and four are coined as ‘deep sleep’ with delta brain waves. Delta waves are slow frequency waves, with high amplitudes, during non-REM sleep. Disruptions to delta wave activity manifest into an ample amount of disorders. The salient feature of stages three and four is that there is absolutely no eye movement or muscular activity. In fact, stage four typically lasts between “20-40 minutes and sleep begins to lighten, ascends to stage two for 10-15 minutes, and suddenly enters a brief period of REM sleep” (Bear et al., 2007, p. 596).

Finally, stage five contains REM sleep, which encompasses brain waves that are comparable to those while awake. Interestingly, this stage is similar to being awake due to rapid eye movement, irregular and shallow breathing, and increased heart rate and blood pressure; however, the muscles and limbs become temporarily paralyzed as a precaution to prevent physical harm while dreaming. In fact, “roughly 75% of total sleep time is spent in non-REM and 25% in REM, with periodic cycles between these two stages throughout the night” (Bear et al., p. 596). As we age, we progressively spend less time in both REM sleep and deep sleep, the stage immediately before REM sleep. During
infancy, babies remain in REM sleep over half the time, and can even fall immediately into the REM stage during sleeping; however, after infancy, this percentage of REM sleep drops to nearly a quarter (Bear et al., 2007) and remains as such until adolescence when the body begins to stay in the lighter sleep stages of non-REM sleep. The entire sleep cycle (i.e., five stages) approximates ninety minutes in total, with each REM stage lengthening throughout the night; therefore, the more sleep obtained per night equates to a greater chance of achieving a longer duration of REM sleep.

Sleep stages are already extremely sensitive to both intrinsic and extrinsic factors, particularly to light, as noted earlier with circadian rhythms, which determine the timing and susceptibility of sleep. In fact, studies that exposed individuals to a 23.5-hour or 24.6-hour light/dark cycle in comparison to a 24-hour day, showed abnormal phase shifting of their melatonin rhythms; levels were high during the day and low during the night creating difficulty trying to fall asleep, ultimately leading to sleep deprivation (Lack & Wright, 2001; Foster & Kreitzman, 2004). The farther individuals become removed from their desired normal sleep cycle, the more they accumulate ‘sleep debt’ from a baseline point, which is the amount of sleep needed to be completely rested per individual. By increasing the number of hours slept per night, sleep debt can be reset once that individual reaches their point of “normal” again (Foster & Kreitzman, 2004). Given this consideration, it’s noteworthy to discuss interruptions to this sleep cycle that relate to the college population, more specifically, LED light technology.

**LED Light Technology**

On the electromagnetic light spectrum, “daylight” colors are equivalent to blue-green colors (Foster & Kreitzman, 2004). Previous studies have found some melatonin
suppression from LED white light and fluorescent light; however, more current research (Lack, Partridge, & Wright, 2001; Lack & Wright, 2001; Lockley et al., 2006) is assessing the effects of LED blue-green light in comparison to LED white light and fluorescent light. These recent studies compared experimental groups’ exposure to LED blue/green light, LED white light, and a standard light box. Findings showed that the blue/green LED light produced the greatest melatonin suppression (70%) and greater delay in melatonin secretion under dim light conditions (the dim light melatonin onset or DLMO) by 42 minutes in comparison to LED white light (50% melatonin suppression, 22 minute DLMO) and regular white light (63% melatonin suppression, 23 minute DLMO) (Lack, Partridge, & Wright, 2001; Lack & Wright, 2001; Lockley et al., 2006).

Modern technological advances are increasing the application of LED lighting over incandescent light sources due to its numerous benefits; specifically, the durability of needing little power, lighter weight, smaller product size, bright color illumination, high-efficiency and high-power, with surprisingly low energy consumption, which allows for a longer lifetime (Haim & Zubidat, 2015). Visible LED lights were first introduced in the late 1960’s as low intensity infrared light sources. The first blue LED light source was introduced in the early 1970s, which later became widely available by the 1990’s. Today commercial LED light sources are now visible at very bright intensity levels in both ultraviolet and infrared wavelengths. This lighting can be found in devices, such as cellular phones, televisions, laptops, desktops, tablets, to name a few.

Among adolescents and college students, electronic LED technology usage has increased as a leisure activity prior to bed (Lemola et al., 2015; Demirci, Akgonul, Akpınar, 2015). The National Sleep Foundation (2011) suggests that engagement with
LED technology within one hour before bedtime relates to decreased sleep onset, decreased sleep duration and sleep quality, later wake times, and impaired daytime functioning (Cain & Gradisar, 2010; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015).

Recent studies observing the pre-sleep activities of children and young adults (aged 5-25 years old) are finding that sedentary screen time from electronic media usage is accounting for at least thirty minutes of a ninety-minute window immediately before bed, contributing to later sleep onset, time displacement, depression of melatonin, and increased cognitive arousal (Foley et al., 2013). Van der Lely et al. (2015) found:

In-bed computer and phone usage before sleep has been positively associated with insomnia and negatively with morningness. Because light is the most important zeitgeber (i.e., synchronizer) for the circadian timing system, its emission by computer or multimedia screens (smartphones, tablets, and so forth) impacts the internal clock and thus on circadian physiology … blue LED light has been shown to act most strongly on circadian physiology, alertness, and cognitive performance. (p.114)

For clarification, morningness refers to "the preferred times of day for achieving various activities (i.e., the phase of the circadian clock)...research has shown that individuals can be arranged on a bipolar continuum from high eveningness to high morningness” (Caci, Robert, & Boyer, 2004, p. 79). There are distinct psychological and biological difference between these individuals, including “usual meal times, performance, body temperature, cortisol and melatonin secretion" (Caci, Robert, & Boyer, p. 80).
Sleep disruptions and lethargy have become the primarily reported complaints attributed to mobile phone use before bed (Loughran, McKenzie, Jackson, Howard, & Croft, 2012). Van der Lely (2015) explained that delayed sleep phase syndrome is “a chronic or recurrent inability to fall asleep and wake up at socially conventional times and presents the highest prevalence (.5%-16%) in adolescents” (Van der Lely et al., 2015, p.114), which Van der Lely refers to as healthy males (aged 15-17 years old).

College is one of the most notable periods for accruing inadequate sleep quality, obtaining an insufficient amount of evening sleep, and experiencing excessive daytime sleepiness. Examination of how learning, memory functioning, and attention are substantially impaired due to sleep deprivation will now be explored.

Adolescence into young adulthood has become one of the most notable periods for accruing inadequate sleep quality, obtaining an insufficient amount of evening sleep, and consequently experiencing excessive daytime sleepiness. Further explanation of how learning, memory consolidation, and attention are substantially impaired due to sleep deprivation will now be explored.

**Sleep and Learning**

This study also explores the relationship between college students’ sleeping behavior and academic achievement. Greater understanding about the relationship between sleep and learning that pertain to efficient memory functioning, memory consolidation, sleep disorders, and sleep dysfunctions, which are highly prevalent among the college population, will be further explained (Gaultney, 2010; Cain & Gradisar, 2010).
Research suggests that college results in a substantial increase in responsibilities, such as extracurricular activities, work obligations, academic commitments (i.e., scholarships, grants, and fellowships), housing accommodations, and general domestic responsibilities (Pilcher & Walters, 1997; Curcio, Ferrara, & De Gennaro, 2006; Gaultney, 2010; Onyper, Thacher, Gilbert, & Gradess, 2012; Taylor, Bramoweth, Grieser, Tatum, & Roane, 2013). Culmination of these obligations can have a negative impact on sleep behavior and academic achievement. This transitional period from adolescence into early adulthood for college students makes this stage in development a particularly demanding time, which is why most students deem their first year of college as one of the most stressful periods of their lives (Brown, Soper, & Buboltz, 2001). Routine and consistency from earlier years of living at home are now replaced with disorganization and haphazard schedules, which may correlate to sleep delay, sleep disruptions, and reduced total sleep quality (Brown, Soper, & Buboltz, 2001).

Students who develop a disproportionate sleep schedule will continue to manifest problems falling asleep, waking at an inconsistent time, and feeling overly tired in the morning hours during the weekday(s) when students need to be fully conscious and alert. In fact, there is such a high percentage of college students who report inconsistent sleep schedules comparative to the rest of society that their symptoms can even be categorized with delayed sleep syndrome (Brown, Bublotz, & Soper, 2002, p. 33). This is more serious than the previously discussed excessive daytime sleepiness, which is a condition that is most often experienced, on average, by this population. Because college students have trouble falling asleep until early morning hours, they would require time to sleep throughout the afternoon to reduce any accruement of sleep debt and/or reduce daytime
sleepiness. Otherwise, those affected by delayed sleep syndrome typically experience reduced work productivity and consequently decreased academic achievement due to the progression of delayed wake times from needing to account for substantial sleep debt.

**REM Sleep**

Although the sleep phase cycles were discussed, REM sleep is the specific phase most related to learning and memory consolidation; therefore, it will be further expanded upon. De Koninck, Lorrain, Christ, Proulx, and Coulombe (1989) researched the connection between sleep and learning and stated that, “students who consistently receive less than eight hours of sleep miss some of the last two hours of REM sleep. Those two hours tend to be the most important for integrating new information” (as cited in Buboltz, Brown, & Soper, 2001, p. 132). A substantial problem with sleep deprivation that should be strongly considered is that it reduces the amount of REM sleep due to shortened and/or interrupted sleep sessions. Research findings portray that the REM sleep stage produces the most influential effects related to memory and performance (Chernik, 1972). In fact, Bear, Connors, and Paradiso (2007) state, “depriving humans or rats of REM sleep can impair their ability to learn a variety of tasks” and in fact, “some studies even show an increase in the duration of REM sleep needed after an intense learning experience” (p. 601). Karni, Tanne, Rubenstein, Akenasy, and Sage (1994) had participants repeat a challenging visual task repeatedly over several days with participants becoming faster at processing the visual task with both time and experience. However, interestingly, findings showed that performance had substantially improved after a full nights’ rest, but if participants were deprived of REM sleep, their learning/comprehension of the task failed to show any improvements (p. 681).
While the body is sleeping, neuron cells remain active and continue firing electrical impulse signals in patterns and stages throughout the night. Moruzzi (1965) was the first to propose that sleep, “a prolonged period of inactivity,” was “required for the recovery of brain neurons” (p. 346) or the recovery of synapses directly involved in learning. During sleep, the brain begins to replay the day’s activities and begins transferring memories between the hippocampus (i.e., temporary memory storage) and the neocortex (i.e., long-term memory storage) because there is a lack of interference from external incidents throughout this time. This transfer presumably ‘erases’ information being held within the short-term storage, thus permitting acquisition of new information (Chernik, 1972, p. 283). Because learning is associated with acquisition, consolidation, and recall, REM sleep aids in consolidation of memory by pruning unnecessary synaptic connections. This alleviates space in the hippocampus for faster processing of information and more relevant material to be retained and consolidated.

**Learning**

Examining the neurophysiological aspects of how learning acquisition is affected by sleep deficiency or sleep inadequacy provides partial insight into the resulting outcomes on academic achievement; however, the behavioral facets resulting from sleep alterations need to be considered as well to highlight the importance of consistent sleep schedules for the college population examined in this study. Several research studies will be elaborated upon to emphasize this point.

The recommended amount of total sleep for adolescents is “8 hours, 30 minutes to 9 hours, 15 minutes,” however, “college students’ sleep has decreased from 7 hours and 45 minutes in 1969 to 7 hours in 2009” (Taylor & Bramoweth, 2010, p. 610). Even more
concerning is that students are not cognizant about the resulting effects of their sleep deprivation. Pilcher and Walters (1997) collected data from 44 (26 women; 18 men) college psychology students (mean age = 20.5 years) regarding the effects of sleep deprivation on cognitive performance and psychological variables after either 24 hours of sleep deprivation or 8 hours of sleep. The researchers generalized that sleep-deprived students performed significantly worse than their peers who were not sleep-deprived. Interestingly, students who were sleep-deprived rated their own performance substantially higher than their peers, despite their poor grades showing otherwise. When students became aware of their performance grades, the sleep-deprived group of students could not understand the correlation between their decreased cognition from all-night studying and lowered test grades (p. 125). Students who slept a total duration of eight hours a night but slightly shifted their sleep-wake cycle by only two hours experienced significant changes in concentration, sociability, and depression (Brown, Buboltz, & Soper, 2002). Moreover, regardless of what time during the day students did study, they typically placed the blame of their poor performance on external/inside factors (e.g., new social opportunities, difficult studies) because, ultimately, the amount of hours spent studying was their primary rationality.

Students with early university classes during the week have also been shown to have the greatest variation in sleep-wake cycles when compared with students with later class times (Brown, Buboltz, & Soper, 2002). Students with “more variations in their sleep schedules had shorter sleep duration and greater difficulties awakening during the week” (Brown, Buboltz, & Soper, 2002, p. 34). Not surprisingly, maintaining consistent
sleep-wake times is suggested as another salient means toward upholding sleep quality and reducing sleep discrepancies.

Dotto (1996) found that memory consolidation and new learning tasks are extremely susceptible to significant modifications if sleep loss occurs during “vulnerable ‘sleep windows’ for several days afterward” (p. 1193). Dotto (1996) found that the first and third night, and all the nights thereafter were highly susceptible to new procedural information. Interestingly, the second night was night not affected by sleep deprivation, so long as new complex information was not learned that day. Cognitive procedural tasks require consistent, on-going learning over time (mastery learning), and are heavily dependent on REM sleep. A lack of REM sleep can “cause substantial deficits in the ability to recall learned tasks” (Dotto, p. 1195). Dotto (1996) goes on to explain that to “retain complex information, getting all your normal REM sleep, at the time your body is conditioned to have it, provides the best results” (p. 1195).

Although college-age students are supposed to acquire no less than approximately eight hours of quality sleep per night, there is a general misconception that any amount of sleep will suffice. Related studies have found that even “partial sleep deprivation (less than six hours of sleep per night), can lead to substantial deficits in attention, concentration, memory, and critical thinking, along with increased depression, irritability, and anxiety” (Brown, Buboltz, & Soper, 2002, p. 34).

Aside from these studies, there is limited exploration of how delaying sleep and sleep deprivation can affect learning with regards to the college population. Most sleep studies have remained focused on K-12 students. Wahlstrom (2002) reported significant benefits from shifting the start times of seven high schools within the Minneapolis public
school district from 7:15 a.m. to 8:40 a.m. Findings included: improved attendance, improved enrollment rates, less sleeping in class, and less student-reported depression. Carskadon, Wolfson, Acebo, Tzischinsky, and Seifer (1998) researched the effects of school start time transitions between ninth graders (8:25 a.m.) and 10th graders (7:20 a.m.). Twenty-five females and fifteen males (ages 14 to 16) were enrolled. Assessments were given at each grade, spring for ninth grade and fall for tenth grade (Carskadon et al., 1998). Participants kept sleep journals for two weeks and wore activity monitors on their wrists for further evaluation. During the 22-hour lab evaluation, evening saliva samples were taken every 30 minutes in dim light to determine salivary melatonin onset phase (DLSMO), overnight sleep was monitored, and the multiple sleep latency test (MSLT) was given. That sleep onset times remained consistent at 10:40 p.m. for both grade levels (Carskadon et al., 1998). On weeknights, total sleep duration dropped from 7 hours and 9 minutes in ninth grade to 6 hours and 50 minutes in tenth grade. This finding implies that adolescents fail to receive any amount of sufficient sleep duration that is close to the required 9 ¼ hours recommended for this cohort. Additionally, the tenth graders’ multiple sleep latency test (MSLT) scores projected a sleep disorder similar to narcolepsy. Students did wake-up earlier on weekdays, but only by 25 minutes as opposed to the 65-minute change in the school start times (Carskadon et al., 1998).

Although research has found effects from sleep phase delay for teens and adolescents, there remains a decrease in school start times with each grade level “from 8:45 a.m. in grammar school to 8:00 a.m. in middle school or junior high school, and then to 7:30 a.m. or 7:15 a.m. or earlier in high school” (Carskadon et al, p. 872).
Despite the relevance of increased LED technology usage before bed, sleep deprivation, and the affects both variables may have on academic achievement for the college population, sufficient research on these issues is still lacking. This is surprising, because college-aged students are faced with a considerable amount of biological and social factors that contribute to sleep deprivation (Gaultney, 2010), decreased total sleep time, inconsistent sleep/wake patterns, later bedtimes/wake times, and reduced sleep quality. Each of these factors can equally affect academic achievement (Wolfson & Caskadon, 2003).

Now that the neurophysiological and state changes of sleep onset, sleep behavior, and sleep deprivation relating to learning acquisition and academic achievement have been discussed, behavioral mechanisms of academic achievement, such as motivation, learning strategies, and achievement goals, will be explored, as this is the second considerable aspect of this study.

**Academic Achievement**

Based on the previous sections, we now understand this undue stress may coincide with pre-sleep activities (i.e., LED technology usage) affecting sleep schedules, resulting in significant sleep debt (Pilcher & Walters, 1997; Gaultney, 2010). Conversely, equally as important to sleep and sleep behavior during college is academics, particularly academic achievement as this relates to academic success. However, academic achievement is a rather broad term. Therefore, all the concepts that encompass the measurement scales used within this study that pertain to academic achievement will be
discussed below to provide a more specific understanding of what this study refers to as academic achievement.

**Motivated Strategies for Learning**

The concepts underlying the motivated strategies for learning questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991; 1993) are summarized in Table 1. The MSLQ was selected because it is a very reputable, well-established scale that is used by numerous scholars within the field of education, typically with a research focus on motivation and achievement.

<table>
<thead>
<tr>
<th>Motivated Strategies for Learning Questionnaire</th>
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<tr>
<td><strong>Motivational Scales</strong></td>
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<td><strong>Value Components</strong></td>
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<td>Intrinsic goal orientation</td>
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<td>Extrinsic goal orientation</td>
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<td>Task value</td>
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<td><strong>Expectancy Components</strong></td>
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<td>Control of learning beliefs</td>
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<td>Self-efficacy for learning &amp; performance</td>
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<td>Test anxiety</td>
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<td>Help seeking</td>
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The MSLQ contains two main scales: motivation and learning strategies. First, the motivational scale elaborates on *value* components (i.e., intrinsic, extrinsic, and task value) and *expectancy* components (i.e., control beliefs, self-efficacy for learning and performance, and test anxiety). The learning strategies scale elaborates on *cognitive and*
metacognitive components (i.e., rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation) and resource management components (i.e., time/study environmental management, effort regulation, peer learning, and help seeking). These two scales will be discussed in more detail below.

**Motivation**

Because the MSLQ is primarily based on motivation, this section begins by introducing the term. Motivation is a multifaceted concept, which represents an explanation for traits and characteristics pertaining to behavior, actions, needs, motives, and desires. Broadly speaking, motivation can be perceived as a state that increases and arouses actions, guides desired direction, and maintains persistence among those activities (Eccles & Wigfield, 1995; Pintrich, Smith, García, & McKeachie, 1993). However, specifically considering motivation from an educational standpoint, the term becomes more concentrated on exploring students’ academic engagement, strategies, perseverance, achievement measures, and assistance seeking.

Given this definition, it is unsurprising that intrinsic motivation would be the first “value” component of the MSLQ, as most educators are consistently trying to instill or enhance intrinsic drive within students because it tends to sustain drive towards academic achievement despite adversities students may face. However, this internal value of motivation is seen as more of a personality trait or inherent characteristic because it is an involuntary need to seek desires and overcome difficulties. Unlike other forms of motivation, intrinsic motivation does not require any external incentives or punishments because learning and achievement suffices as enough of a reward to the individual (Sansone & Harackiewicz, 2000).
Considerations of intrinsic motivation became more prominent in the latter half of the 20th century and despite the array of newfound theories to explain this concept, four terms best encompass all the principles: challenge, curiosity, control, and context (Sansone & Harackiewicz, 2000, p. 258). Collectively, the overarching theme for intrinsic motivation is that individuals will continue to purposefully pursue challenges and/or obstacles to overcome in order to achieve the satisfaction of personal gratification, achievement, and self-growth (White, 1959; Sansone & Harackiewicz, 2000). For instance, a very simplistic example of intrinsic motivation is when infants continually try to master walking despite numerous falls and failed attempts, not expecting to receive any external reward. As individuals adapt to novel situations throughout life, they will continuously attempt to ease that accommodation by trying to control goal-directed actions to ultimately avoid failure and/or negative consequences. It is common to expend effort while transitioning through the developmental stages to explore curiosities in order to achieve a greater understanding of the environment and cultural surroundings (Berlyn, 1960; 1966). Environmental and contextual dynamics of the atmosphere play a significant role in intrinsic motivation. Lepper, Greene, and Nisbett (1973) exemplified this point by using a sample of kindergarten children with high intrinsic motivation for drawing and randomized them into three groups (given reward, random-reward, and no-reward). that those children in the ‘guaranteed reward given group’ for their work showed reduced self-interest in drawing afterwards, whereas the other two groups did not. Findings confirmed the ‘overjustification hypothesis’ of the study that intrinsic interest in an activity and/or task will decrease when participation is forced as a way to obtain an extrinsic reward.
“Making sense of one’s own environment, overcoming challenges, exercising control, and enjoying individual competence are intrinsic human desires or needs” (Sansone & Harackiewicz, p. 320). As prior information implied, intrinsic motivation is a culmination of self-determination, a perceived degree of autonomy, novel stimulation, and environmental influences. However, as students’ age, academic coursework tends to become more rigorous and lecture-based, and in turn, social interactions and extracurricular activities become more of a priority. Ultimately, this decreases creativity and excitement, along with interest and sheer enjoyment. Lepper, Sethi, Dialdin, & Drake (1999) explained there is "strong evidence of a decrease with age in students' intrinsic motivation in school...as children grow older and progress through school...they learn to take increasingly seriously the extrinsic indicators of success or failure in school" (p. 32). As students’ attitude, drive, and motivation towards education begins to decline, research shows that extrinsic motivation becomes supplemental to maintaining their interest and drive.

The opposite of intrinsic motivation is extrinsic motivation, which is garnered from an incentive, reward, or a form of success attached to a societal expectation (Sansone & Harackiewicz, 2000). Types of extrinsic motivation (i.e., external rewards) tend to distract an individual from behaviors that are inherent to their intrinsic state and/or redirect focused attention on behaviors that seek more pleasurable rewards in exchange for a designated ‘cost’ or outcome. Influential learning and extrinsic motivation became the centerpiece of motivational research in the beginning of the 20th century (Sansone & Harackiewicz, 2000). Research studies at this time varied in procedures, however, each had a very similar objective to document the degree of behavioral
modification on subjects from an externally imposed instrument. Findings consistently showed that if the altered behavioral state was in accordance with the initial desire, then reinforcements and/or incentives would be instilled to reiterate that behavior as being correct to the subjects, which would ultimately create a conditioned learning effect (Sansone & Harackiewicz, 2000).

Understanding extrinsic motivation allows for a better transition into task value, which is the last aspect of the value components embedded within the motivational scale portion of the MSLQ. Task value can be perceived as an expected reward an individual will receive from partaking in an activity. This ‘reward’ can be either a direct result of engaging in a particular activity itself or indirectly if the activity played a contributory role in obtaining an outcome from an alternative source (Eccles & Wigfield, 1995). The level of value arises from the perceived valence towards an event, object, or situation by its appearing either attractive (i.e., positive valence) or aversive (i.e., negative valence). Valence pertains to the degree of value placed on the reward of an outcome. Value level will vary in motivation depending on factors such as an individual’s needs, wants, goals, and performance abilities. Because valence can be viewed as self-indulgent, this further affects an individual’s approach or avoidance behavior towards goal attainment.

Eccles and Wigfield (1995) proposed that task-value could be “conceptualized as four major components: attainment value, intrinsic value of interest, utility value, and cost” (p. 216). Attainment value is simply the value or level of importance an individual attaches to a task for his or her self and/or identity. A higher place value entails a greater expenditure of effort, engagement, and commitment to success and/or completion (Wigfield, 1994a; 1994b). As previously discussed, intrinsic value is merely the internal
drive and/or personal enjoyment an individual gains from undertaking a given task. Utility value correlates more with extrinsic motivation because it represents an individual’s measurement of usefulness and/or evaluation of possible outcomes with partaking in the said task for long-term use or future plans. Finally, the degree of cost is the evaluation of both the negative (e.g., anxiety, failure, loss of time, high effort demands, loss of higher value alternatives) and positive aspects of engaging in the task (Wigfield & Eccles, 1992). More specifically, cost refers to “how the decision to engage in one activity (e.g., doing schoolwork) limits access to other activities (e.g., calling friends), assessment of how much effort will be taken to accomplish the activity, and its emotional cost” (Wigfield & Eccles, 2000, p. 72). This covers the value components within the motivational portion of the MSLQ. Now the expectancy components, which again encompass learning beliefs and self-efficacy, of the motivational scale will be discussed.

Expectancy or expectation strongly pertains to motivation, because it refers to an individual’s belief system regarding his or her perceived ability to successfully partake in a task, regardless of whether that task is in the present or future tense. Atkinson (1957) explained motivational expectancies as cognitive anticipations, typically aroused by cues in a situation, that either enhance certainty or uncertainty about an individual’s level of performance capabilities that will either lead to success or failure on a given task.

The next aspect of expectancy entails an individual’s control of learning or learning beliefs. Learning, in this regard, relates to an individual’s conviction that they can control their behavior and, quite possibly, the degree of their own ability to achieve a desired outcome. Learning beliefs further encourage a mastery-goal orientation because
students who uphold this perception are more likely to regularly attend classes, engage in course discussion, remain disciplined to the homework, and maintain consistent study habits (Zimmerman, & Risemberg, 1997; Pintrich et al., 1993). Learning beliefs support the belief that students can aid in their desired academic outcome and success, which consequently increases academic achievement and motivational behavior.

The final portion of the expectancy components is self-efficacy, which relates to an individual’s expectation of success along with their personal perception regarding their own capabilities (Duncan & McKeachie, 2005; Garcia & Pintrich, 1995; Pintrich et al., 1993). Self-efficacy relates to an individual’s evaluation of their competence to complete a specific task, yet has little, if any, correlation to their self-worth or self-esteem (Sherer et al., 1982); to be clear, they are separate measures of self. This self-assessment tool can significantly influence motivation because having high self-efficacy will encourage the decision to engage in challenging tasks, expend greater effort, persevere through adversity, and apply problem-based coping strategies to tasks, while ultimately reducing fear and anxiety with each successful achievement (Bandura, 1982; 1989; Zimmerman, & Risemberg, 1997). Self-efficacy is a product of both operant conditioning (i.e., “I can do this”) and classical conditioning (i.e., palms sweating, heart pounding), which are learned behaviors from repeated exposure, previous experiences, observations, or physiological responses to heightened situations (Bandura 1982; 1989; Schunk 1989; 1995). For increased self-efficacy, a student must first understand its importance to learning and how low self-efficacy can significantly hinder their academic achievement.
Understanding the value-expectancy factors that encompass the motivational aspect of the MSLQ provides greater explanation about an individual’s motives and self-perceptions towards goal attainment. Now the learning strategy components of the MSLQ will be presented to provide a complete depiction of the measurement tool.

**Learning Strategies**

The second aspect of the motivated strategies for learning questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) relates to various learning strategies that are significant to academic achievement. Like the previous section, it is best to begin by first explaining what is meant by learning strategies. Therefore, learning strategies specifically referenced in the MSLQ relate to various forms of rehearsal, elaboration, and organization with critical thinking as the overarching approach to affectively apply each strategy to enhance learning.

The primary goal with a mastery approach to learning entails the use of various strategies to retain information, so it can be quickly recalled and then effectively applied when needed. When trying to successfully accomplish any task, strategic effort is always necessary. By using effective learning strategies, these processes become more automatic, making it easier for the student to learn more efficiently (Alexander, Graham, & Harris, 1998). This description implies that higher executive functioning is required when developing learning strategies. Higher executive functioning pertains to various mental skills performed within the frontal lobe of the brain to assess, reason, rationalize, and decipher the best approach strategy towards a problem, goal, or complex/novel information. This substantiates why the first component being discussed within the learning strategies scale is cognition.
Examining learning strategies from a purely cognitive perspective entails the acquisition of new information to become an extension or addition of existing knowledge, ultimately transforming prior conceptions. This process is a developmental progression or mental construction of new neural connections to related information. Pursuit of any goal is not an unconscious process; people are selective with their perceptions, behaviors, actions, and decisions along the way (Anderson, Reder, & Simon, 1996). Newly acquired information or realization during this approach is always evaluated, analyzed, and implemented into new knowledge, so the individual can maintain persistence and consistency towards a goal.

Learning strategies enhance the mental formation of new neural connections to related information. Therefore, the selection of the most appropriate strategies to use are applied during the acquisition of novel information, allowing the individual to better evaluate and analyze the material so persistence and consistency towards an end-goal prevails (Anderson, Reder, & Simon, 1996).

Metacognition is the first component of learning strategies that will be discussed. Metacognition is when an individual uses their higher thought control processes to manage their own thinking and regulate their problem-solving capabilities to enhance their learning. This process allows individuals to consistently assess their application strategies to each task and evaluate the effectiveness. William James, the father of psychology, first introduced metacognition nearly a century ago by expressing how the study of the mind should be a direct, internal reflection of consciousness or introspection. Subsequently, as stated by Fleming and Frith (2014), James describes introspection as, “a self-reflective, retrospective process in which one’s memory trace of the original target
mental state is inspected” (p. 69). Although consciousness and introspection used to be interchangeable, we are now aware that metacognition is a more accurate term than consciousness. Metacognition relates to a higher-order process, requiring complex neural processes, to concentrate on cognition as it is objective, whereas introspection is a higher-order process with an emphasis on conscious experience.

Metacognition is most effective during challenging tasks, because it requires an additional set of skills that further regulate thinking and learning: goal setting, planning, self-motivation, attention control, application of learning strategies, self-monitoring, help-seeking, self-evaluation, and self-reflection (Zimmerman & Bandura, 1994; Bear, Connors, & Paradiso, 2007). The greater metacognition is developed and expanded upon within an individual, the more quickly and efficiently learning and improvement is acquired. Enhancing metacognitive abilities will better allow a child to grow in their acquisition of knowledge comprehension.

This leads to critical thinking, which coincides with cognition and metacognition, and is another significant component within learning strategies. This concept implies that individuals objectively judge novel information for the credibility and integrity, which requires piecing information together (knowledge acquisition and accommodation) from various sources to rationalize the concept. Critical thinking is an imperative form of higher complex cognitive processes because students use it to evaluate a concept(s) by collecting information from multiple sources to rationalize, then take an objective stance, inquire more information for greater validation, and finally, review the evidence for credibility. In conjunction to critical thinking is self-regulation, which is developed progressively from self-guided or self-directed learning opportunities or activities that
enhance independence at each age. However, Pintrich (1999) provides a more narrowed description, defining self-regulation as, “monitoring, controlling, and regulating cognitive activities and actual behavior” (p. 461). Though the fundamental definition may vary, the primary factors of self-regulation entail: goal setting, planning, self-motivation, attention control, application of learning strategies, self-monitoring, appropriate help-seeking, and self-evaluation (Zimmerman & Bandura, 1994).

Collectively, these learning strategy cognition components give an individual more control when adjusting to newly acquired knowledge (Pintrich, 1999). Students who possess these capabilities are better able to control and monitor their own cognition (Duncan & McKeachie, 2005; Garcia & Pintrich, 1995; Pintrich et al., 1993). This likely explains and supports why self-regulation has become such a frontrunner among educational institution goals for students, because it enhances the neural cognitive processes that aid in positively influencing student learning and academic achievement.

In relation to behavioral advantages of self-regulation, the particular areas in which it could benefit students the most is, “mood control (e.g., anxiety, anger, frustration), goal setting, concentration, procrastination, and time management” (Zimmerman, & Risemberg, p. 91). A student might be highly motivated but lack focus and attention due to distractions, which ultimately delay completion of the task. This reiterates the importance of adapting self-regulatory skills, so problems can be alleviated independently both in the short and long-term.

**Resource Management Strategies**

Resource management concepts are the final component within the learning strategies scale of the MSLQ. However, because they are not purely cognitive learning
strategies, they will be explained separately from the previous concepts. These fundamental resource tools that students use to manage and regulate a situation (e.g., managing time, controlling study location) enable students’ greater control in adjusting and modifying their environment to better fit their needs and desires to ultimately reach their goals and/or objectives (Pintrich, 1999, p. 462).

The first, time management, involves “scheduling, planning, and managing one’s study time. This includes not only setting aside blocks of time to study, but the effective use of that study time, and setting realistic goals” (Pintrich et al., 1991, p. 25). Time management can be short-term or long-term goals, but ideally scheduling designated work time should be held accountable and realistic. Work environment is as equally significant as time management, because distractions, disorganization, and noise level are all substantial contributory factors that aid in procrastination and task delay (Pintrich et al., 1991).

Next is effort regulation, which is a facet to the above-mentioned, self-regulation. However, effort regulation relates to maintaining diligence and perseverance when tasks are uninteresting and/or distractions are prevalent. Use of this learning strategy accentuates a strong commitment to goal achievement along with continued use of strategy skills (Pintrich et al., 2000).

Furthermore, peer interaction and group work tends to support outcomes with achievement and learning, enhancing students’ range of proximal development. Because stimulating tasks enhance cognitive advancement, proximal development is deemed the range an individual cannot perform independently on tasks, but can with the guidance of others (Aljaafreh & Lantolf, 1994; Vygotsky, 1987). Engagement with classmates may
enhance material comprehension because of the ability to easily relate to one another. Collaboration with peers can also benefit highly gifted students who do not need further interpretation but can refine their own understanding from explaining to others (Aljaafreh & Lantolf, 1994). Help seeking is the final concept of resource management strategies, which Newman (1994) expressed as the choice to seek adaptive help (e.g., reciprocal questioning and collaborative teacher-student involvement) to better regulate the learning process is done through a filtered motivational-affective system that includes students’ belief of competence, achievement goals, and perceptions (Newman, 1994, p, 285-286).

Collectively, motivation and learning strategies are the main facets that comprise the motivated strategies for learning questionnaire (MSLQ), but more importantly, the concepts provide a comprehensive understanding of academic achievement. Next, achievement goal theory will be explored because this measurement scale is also used within this study. Understanding this theory is essential because it also relates to this study’s description of academic achievement.

**Achievement Goal Theory**

There is, to a degree, a relationship between motivation, academic achievement, and goal setting (Zimmerman, & Risemberg, 1997). However, because motivation was heavily explored in the previous section, this will not be discussed, but rather another related concept will be explored, achievement motivation. This entails a significant need for achievement to avoid the fear of failure, ultimately encouraging complex cognitive thinking resulting in the potential of adopting either a positive or negative mindset. Conversely, academic goals tend to increase sustained focus, encourage greater
determination and commitment, enhance tenacity, and support the use of strategy selection when other methods fail. Finally, achievement goals are “constructed as more concrete, midlevel cognitive representations that direct individuals toward specific end states” (Elliot & McGregor, 1999, p. 628). Achievement goals are said to have a primary influence on outcomes, whereas achievement motives are secondary. For clarification, achievement motives may be referred as “a motivational tendency, a broad desire to approach success, and a motivational tendency or broad desire to avoid failure” (Sparfeldt & Rost, 2011, p. 497). More importantly, both complement one another and both harmonize achievement behavior (Elliot & McGregor, 1999). Table 2 summarizes the concepts within the achievement goal theory 3x2 model.

Table 2

<table>
<thead>
<tr>
<th>Valence</th>
<th>Definition</th>
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<tr>
<td>Absolute (task)</td>
<td>Intrapersonal (self)</td>
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<tr>
<td>Positive (approaching success)</td>
<td>Task-approach goal</td>
</tr>
<tr>
<td>Negative (avoiding failure)</td>
<td>Task-avoidance goal</td>
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The culmination of these three broad concepts – motivation, academic achievement, and goal setting – yield both performance and mastery goals, which lay the groundwork for achievement goal theory. More specifically, achievement goal theory encompasses, “performance-approach goals (i.e., focused on the attainment of competence relative to others), performance-avoidance goals (i.e., focused on avoiding...
incompetence relative to others), and mastery goals (i.e., focused on the development of competence and task mastery) (Elliot & McGregor, 1999, p. 628).

Before performance and mastery goals are expanded upon, it is first important to understand that competence is the underlying concept to this framework. Ryan and Pintrich (1997) explain competence as, “perceived cognitive competence refers to students’ perceptions of their academic abilities, that is, the belief that they are capable of understanding and doing their schoolwork” (p. 329). Students who claim this quality are more inclined to use effective learning strategies, metacognition, and self-regulation to their advantage. At this point it is noteworthy to express that these concepts are similar to the fundamental components of the previously discussed MSLQ scale, which emphasizes that both measurements coincide in creating an overall depiction of academic achievement. Cognitive competence may be attributed to the level of influence on academic achievement and perseverance to goals during challenges (Dweck, 1986; Dweck & Leggett, 1988).

As a subsidiary note, competence may also be subcategorized to include the perspective of social competence. Social competence regards positive interaction with peers (making friends) and feeling inclined to possess better social interaction abilities (e.g., being easily liked). Although social competence is not relevant to this study, it is worth mentioning because positive correlations have been found between social competence, academic achievement, and school adjustment (Ryan & Pintrich, 1997). Future studies should further explore the relationship(s) between the social considerations of competence and academic achievement.
In achievement goal theory, competence is the underlying concept of goal orientation. Competence reflects an individual’s adequate knowledge of usable skills or capabilities to successfully and effectively complete a task. This level of competence will aid in the approach towards a goal as being more performance or mastery oriented (Elliot & McGregor, 1999). As previously expressed, a performance-approach orientation is a “focus on the attainment of competence relative to others,” and performance-avoidance orientation is a “focus on avoiding incompetence relative to others,” and mastery goal orientation is a “focus on the development of competence and task mastery” (Elliot & McGregor, 1999, p. 628). Situational dynamics will change each goal orientation to either performance-based or mastery-based, but the level of initial competence an individual withholds will be a significant factor in deciding the approach method for the completion of any task.

The first goal orientation of achievement goal theory is performance goals, which are occasionally referred to as ability or ego goals. These can be foreseen as a personal objective of wanting to appear fully proficient or capable to others. Performance goal orientation is purely extrinsic in which students use external factors (e.g., GPA, scholarships, financial aid, class ranking) as their motivational drive (Meece, Anderman, & Anderman, 2006). Elliot and McGregor (1999) further distinguished performance goals into: performance-approach goals and performance-avoidance goals (Elliot & Church, 1997). Performance-approach orientation is concerned with a desire to achieve a positive perception from others regarding an achievement level of high capabilities. While, performance-avoidance orientation seeks prevention from a believed conception of lacking abilities (Elliot & Church, 1997; Meece et al., 2006; Pintrich, 2000).
The second goal orientation is mastery goals, which are sometimes referred to as a task or learning goal, with the direct intention of wanting to improve learning and ability level regardless of performance standards or outcomes. Students who are mastery-oriented tend to place greater emphasis on learning and see their capability to improve as fluid. Students with a mastery learning mindset become more engaged in tasks, invest more time and effort into studying, seek help when needed, and commit to submitting quality work (Meece, Anderman, & Anderman, 2006). These students are known to “get lost in their work” (p. 439) because they become oblivious to their peers’ performance. Instead, they are more concerned with meeting their own measure of achievement and comprehension. Additionally, mastery-oriented students have more self-confidence, which strengthens their desire to seek challenges and persevere through struggles. Finally, Pintrich (2000) further dissected mastery goals into mastery-approach goals and mastery-avoidance goals. A mastery-approach orientation concerns a students’ objective to learn, comprehend, and fully understand the material. Conversely, mastery-avoidance orientation relates to the fear of failure to learn from an assignment or lacking complete comprehension of the content (Meece et al., 2006, p. 491).

The final component of achievement goal theory is valence. This term refers to the amount of value, either positive or negative, that is given to a desired and/or expected outcome from a task. More specifically, valence can be perceived as the amount of stress or significance that an individual gives a specific outcome (Linnenbrink & Pintrich, 2004). The amount of valence or emotional orientation given to an outcome will also strengthen the amount of designated effort exerted. Consequently, if little value is given
to the outcome then the individual must not perceive the available rewards as worthy enough of their time commitment (Linnenbrink & Pintrich, 2004).

In 2011, Elliot, Murayama, and Pekrun edited their original 2x2 achievement goal framework (Elliot & McGregor, 2001) into a 3x2 model, with the hope that the alteration would further understand a student’s reason for the pursuit of a goal, as opposed to just focusing on the aim or result. This was done by further portioning mastery goals into: task, self, and/or other. Elliot et al. (2011) contended that a learner’s competence could be assessed by the following evaluative principles: task-oriented standards, self-oriented standards, and other-oriented standards against their level of valence (approach/avoidance). Task-based and self-based goals best align with mastery-approach and mastery-avoidance goals. Students will decide the level of valence to give a goal because they are either focused on attaining task-based or self-based competence or avoiding task-based or self-based incompetence. Conversely, other-based goals best align with performance-goals. Individuals will evaluate their efforts based on the attainment of other-based competence or the avoidance of other-based incompetence. The overarching objective with this revised framework was the desire to obtain even greater awareness about student efforts, as this will provide more insight about academic achievement and mastery goals.

Focus

A final noteworthy facet of academic achievement is the idea of sustained attention towards something of value or interest. The term ‘focus’ is both mentioned and embedded within the concepts described in the MSLQ and AGT, but is uniquely
individualistic and often overlooked. Focus is a necessary component to any goal, whether intrinsically or extrinsically motivated. Depending on the learner’s academic objectives, their focus will shift or vary per goal acquisition, but it remains a “prerequisite to learning and a basic element in classroom motivation and management” (Sylwester & Cho, 1993, p. 71). Understanding the mental processes that monitor and sustain focus allows educators to better regulate student attention through effective strategies that trigger brain and behavior mechanisms as opposed to promoting limited practical knowledge.

Goleman (2015) suggests that focus is hardly noticed and an under-rated mental asset that matters enormously in how people navigate life. Goleman reviewed the importance of focus, calling it the hidden driver of excellence. Using evidence from competitive sports, education, the arts, and business, he concluded that an essential characteristic of high-achievers is their ability to focus. Goleman (2015) demonstrated the importance of being able to direct and sustain focus, and argued that people must sharpen their focus if they are to contend with and thrive in, a complex world. Other research indicates that maintaining focused attention activates several neural networks in the pre-frontal cortex of the brain, including the alerting network, the orienting network, and the executive attention network. The development of these networks may be linked to higher levels of academic achievement and performance, such as concentration, selective attention, comprehension, memory, and learning in students (Wilson & Conyers, 2011; Goleman, 2013).

Focus can be strengthened, like a muscle, by consistently redirecting attention to maintain concentration despite distractions by connecting reasons to focus to either:
inner, other, or outer objectives (Goleman, 2013). Inner focus concerns intrapersonal affairs related to intuition, internal decisions, and guided values. Other focus regards interpersonal issues with peers and classmates. And outer focus pertains to larger scale issues and objectives that relay to society or large-scale affairs. These three concepts parallel the three approach/avoidance principles of the AGT: self, task, and other goals.

Prolonged use of electronic devices cause students to have trouble focusing. The excessive time today’s youth is spending on technological devices has helped them acquire specific neurological cognitive and technical skills, but is simultaneously causing significant deficits in other neural correlates that relate to core mental skills (Goleman, 2013). “As we focus on what we are learning, the brain maps that information on what we already know, making new neural connections…when our mind wanders…lacking focus, we store no crisp memory of what we’re learning” (Goleman, p. 15). Furthermore, sleep deprivation is known to be associated with an inability to concentrate (Alapin et al., 2000) and increased fatigue (Samkoff & Jacques, 1991) both of which may influence a students' ability to focus in and out of class and result in lower level of achievement.

**Conclusion**

This study explores how LED light technology usage prior to bedtime affects sleep behavior and academic achievement of college students. Outwardly these concepts may appear to be uniquely different, but it is the neural underpinnings of the brain activity that bridges each of these seemingly unrelated topics, together. Hopefully it is now clear that learning initially begins with the formation of new neural connections within the brain that are created from acquisition and/or adaptation of new information,
and is retained through memory consolidation during sleep. The primary source of all thoughts, feelings, behaviors, actions, drive, arousal, energy, and motives originates in the brain. Sleep is merely one influential component on these mechanisms; however, it is a very critical one.

College is a highly sensitive time in development when students need a substantial amount of sleep (Bear, Connors, & Paradiso, 2007) for proper neural functioning, peak cognitive arousal, elevated moods, and sustained mental concentration. The increase in extracurricular activities (i.e., jobs, social obligations, domestic priorities) creates enough of a significant impact on sleep and academic achievement. The additional influence of LED light stimulating technology usage before bedtime offsets the circadian rhythm(s) within the brain and throughout the body, along with sleep schedules, all of which can be quite detrimental to a college student’s success.

As previously stated, academic performance is certainly an easier facet to assess academic success; however, academic achievement coincides with mastery learning, which aligns with the fundamental objectives of education and therefore should not be so quickly bypassed in research studies. By continuing to use mastery-type measurements to assess academic achievement, these tools may start to become more mainstream, and eventually, a common way to measure student learning and success within academic settings and by more researchers.

The measurement scales explored within this study that assess academic achievement are highly reputable and well established. Although overwhelming, the idea with elaborating on all underlying concepts of each scale was to thoroughly emphasize how each connects with sleep, learning, and academic achievement. Given the amount of
information provided, it is evident that learning pertains to a level of higher executive functioning, which strictly relates to neural development and substantiates the importance of sleep quality and sleep duration.
Chapter Three

Methodology

The purpose of this research study is to assess the relationship between LED light technology usage prior to bedtime on sleeping behavior and academic achievement specific to college students.

Technology that contains an LED screen gives off a wavelength that emulates daylight, therefore awakening the brain and stimulating resulting neural structures into thinking it is daytime, and ultimately postponing melatonin onset. This shifts the circadian rhythm by altering the sleep schedule, influences the sleep cycle, sleep duration, and sleep quality, and results in compromised cognitive states that may influence academic achievement and learning.

To date, research lacks any exploration of the relationship between these three specific variables among the college population, which is quite interesting, as findings would provide universities and academic institutions greater insight into improving student achievement and academic success, especially because the usage of LED light technology is continuing to rise.

The research questions pertaining to this study are:

1. How does usage of LED light technology and sleep duration correlate with academic achievement?
2. What is the relationship between LED light technology usage and academic achievement among college students with similar sleep duration?
3. What is the relationship between sleep duration and academic achievement among college students with similar LED light technology usage?
The hypotheses for this study are as follows:

1. College students who report increased usage of LED light technology before bed will report increased time falling asleep and decreased total sleep duration.
2. College students who report increased time falling asleep will report decreased sleep, and decreased academic achievement.
3. College students who report increased levels of academic achievement, will report increased total sleep duration and decreased usage of LED light technology before bed.

**Participants**

This study was designed for a population of college-aged adults, at least 18 years of age. Undergraduate participants were recruited for this study, all enrolled in a four-year degree-seeking program at a large public institution located in the Midwest. Participants were recruited from introductory education courses. At the start of this study, all potential participants received an information page describing the purpose and criteria of the study. By signing-up and completing the surveys, participants acknowledged that they were at least 18 years of age. Although there were no monetary incentives for students participating in this study, research subjects were awarded research credit hours, ultimately fulfilling research credits required by their education class.

**Procedures**

Only the students who completed the first survey in its entirety were emailed the additional weekly survey links. Participants were emailed survey links every Friday afternoon allowing ample time for completion. Surveys were to be completed in their
entirety by Sunday evening before midnight. The original survey was created within Qualtrics, an online survey database. Students were emailed the Qualtrics link through their university email each week. All survey submissions would be automatically uploaded into the Qualtrics database for later review. To receive full research credit for their education course as required by the syllabus, students who chose to participate had to complete each weekly survey from start to finish. Partial credit was not awarded. However, for students who chose not to participate, alternative research assignments were provided so they could still fulfill their research requirements for the class. Students who chose to participate were required to keep a daily log of their sleep habits and behaviors, along with the duration of any other pre-sleep activities. At the end of each week, students were sent an electronic survey, in which they recorded a variety of weekly activities, such as: total time spent in class, total time completing school work outside of class, level of focus in class, level of focus on school work outside of class, total night sleep, total daytime napping, duration of time spent using LED technology prior to bed, duration of time to fall asleep, total times sleep was interrupted by an LED technology while sleeping. Additionally, the end of each electronic survey also included a copy of the Epworth Sleepiness Scale (ESS), the 3x2 Achievement Goal Framework, and some of the subscales from the Motivated Strategies for Learning Questionnaire (MSLQ).

Instruments

A pilot study was initially conducted with undergraduate participants (n=55) for greater understanding of this population. This pilot study had similar questions to the revised, final version of the survey. However, results from the pilot study provided detailed information that allowed for better future survey questions and data collection.
The revised and final survey was created with the Director of Evaluation and Implementation Services at a Midwest university who had more than twenty-years of experience in survey development. Student participants completed a four-part electronic survey every week for three weeks starting near the beginning of the 2017 spring semester (February through March). This survey was comprised of the Epworth Sleepiness Scale (ESS), the 3x2 Achievement Goal Framework, and select questions from the Motivated Strategies for Learning Questionnaire (MSLQ) that related best to this study. Participants’ names were separated from all survey material, ultimately abiding by the Institutional Review Board (IRB) protocol for confidentiality.

*The Epworth Sleepiness Scale (ESS) (Johns, 1991)* is a self-administered questionnaire that measures the general level of daytime sleepiness and/or sleep propensity in adults. The questionnaire consists of 8-items with two additional questions that correlate with this study. The questions provided sought to explore the level of sleep propensity experienced in everyday, common situations most often met throughout daily life activity. The questions asked participants to indicate on a 3-point Likert scale (0=never dozed off; 3=high chance of dozing off) the chances of dozing off during their most recent experience for each scenario. A sample of some of the situations described in the various statements were, “sitting, without movement or idle, in a public space,” “sitting and reading,” and “sitting and talking with someone.”

*The (3 x 2) Achievement Goal Framework* (Elliot, Murayama, & Pekrun, 2011) is an 18-item questionnaire using a 7-point Likert scale (1=not true of me; 7=extremely true of me). This framework is an extension of the 2x2 model (Elliot & McGregor, 2001) 12-question model, which focused on distinct patterns of antecedents and consequences
(i.e., approach-avoidance distinction). The 3x2 framework is a revised version of goal achievement that is more grounded on a competence-based aim of guiding behavior that is solely rooted in task (i.e., absolute competence), self (intrapersonal competence), and other (interpersonal competence). Some items within the AGT model were reworded to better fit this study. The 3x2 model explores six goal constructs: task-approach, task-avoidance, self-approach, self-avoidance, other-approach, and other-avoidance. More specifically, the goal of the 3x2 and 2x2 frameworks are conceptualized on the following:

- a mastery-approach goal focused on the attainment of task-based or self-based competence;
- a mastery-avoidance goal focused on the attainment of task-based or self-based competence;
- a mastery-avoidance goal focused on the avoidance of task-based or self-based incompetence;
- a performance-approach goal focused on the attainment of other-based competence;
- and a performance-avoidance focused on the avoidance of other-based competence (Steel, 2010, p. 633). Each of the six goal items contain three questions, which comprise 18-questions in total, asking the participant to rate each goal statement. A sample of a task-approach goal item is, “to know the right answers to the questions on the exams in this class.” A sample self-avoidance goal item is, “to avoid performing poorly on the exams in this class compared to my typical level of performance.” Finally, a sample of the other-approach goal item is, “to outperform other students on the exams in this class.”

*The Motivated Strategies for Learning Questionnaire (MSLQ)* (Pintrich, Smith, Garcia, & McKeachie, 1991) is an 81-item questionnaire with a 7-point Likert scale (1=not at all true of me; 7=very true of me) designed to measure college students’ motivation and use of various learning strategies to a specific course. However, only four of the
fifteen subscales were chosen for this study. Among the motivation scales, intrinsic goal orientation (4 items), extrinsic goal orientation (4 items), and self-efficacy for learning & performance (8 items) were selected. Within the learning strategy scales, effort regulation (4 items) was chosen. Some items within the MSLQ are negatively worded and must be reversed (i.e., a 1 would become a 7) before computing a final score. Sample questions from the motivation section are, “I think I will be able to use what I learn in this course in other courses,” “I believe I will receive an excellent grade in this class,” and “when I take tests I think of the consequences of failing.” Sample questions from the learning strategies section are, “I make good use of my study time for this course,” “I work hard to do well in this class even if I don’t like what we are doing,” and “I ask the instructor to clarify concepts I don’t understand well.” To reduce participant fatigue, selected questions best related to this study were chosen, reducing the number of total questions provided.

Data Analysis

The response data collected using the sleep study survey, the Epworth Sleep Scale (Johns, 1992), the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993), and the Achievement Goal Theory (Elliot & Peckrum, 2011) were transcribed into an Excel worksheet. Because Excel is incapable of conducting the statistical analysis required to test the hypotheses, the Excel files were imported into the data editor of SPSS vs. 20.4 (Field, 2013). The response data were analyzed with SPSS to (a) summarize the demographic and contextual characteristics of the participants collected with the Demographic Questionnaire and (b) operationalize the variables collected with the Sleep
Descriptive statistics were used to summarize the variables collected with the Sleep Study Survey, the Epworth Sleep Scale, the Motivated Strategies for Learning Questionnaire and the Achievement Goals Framework. There are two types of descriptive statistics (a) parametric statistics (e.g., mean and standard deviation) which assume that the frequency distribution of the variable is symmetrical, and approximates a normal bell-shaped curve; or (b) non-parametric (e.g. median and mode) which assume that the frequency distribution of the variable is asymmetrical, so it does not approximate a normal bell-shaped curve. Before descriptive statistics can be computed, it is necessary to test for normality, although many researchers do not do so, leading to many misleading results in the literature (Ghazemi & Zahediasl, 2012). Kolmogorov-Smirnov (K-S) tests for normality were conducted to determine if parametric statistics were applicable, or if non-parametric statistics were more applicable to summarize the variables. The median was used as a summary statistic if the variable strongly deviated from normality, indicated by $p < .01$ for the K-S test. The reason for using the median rather than the mean is the median is a less biased descriptive statistic to indicate the central value of the frequency distribution than the mean if the variable deviates strongly from normality (Field, 2013).

The mean scores for the variables measured using the instruments administered in this study were compared with the mean scores for the variables measured by the developers of the Epworth Sleep Scale (Johns, 1992), the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993), and the Achievement Goal Theory (Elliot
Independent samples $t$-tests were conducted to compare the mean scores. A statistically significant difference between the variables measured in this study, and the variables measured by the developers of the instruments, was indicated if $p < .05$ for the $t$-test statistics.

Several statistical methods could potentially be applied to answer the following three research hypotheses. H1: College students who report increased usage of LED light technology before bed will report increased time falling asleep and decreased total sleep duration; H2: College students who report increased time falling asleep will report decreased sleep, and decreased academic performance. H3: College students who report increased levels of academic performance will report decreased usage of LED light technology before bed. The hypotheses required evaluation of the statistical relationships between the criterion and predictor variables defined in Table 1.

Table 3

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Criterion variables</th>
<th>Predictor variables</th>
</tr>
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<tbody>
<tr>
<td>H1</td>
<td>1. Time using LED light technology before bed (h)</td>
<td>1. Time to fall asleep (h)</td>
</tr>
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<td></td>
<td></td>
<td>2. Sleep duration (h)</td>
</tr>
<tr>
<td>H2</td>
<td>1. Time to fall asleep (h)</td>
<td>1. Variables measured with Motivated Strategies for Learning Questionnaire</td>
</tr>
<tr>
<td></td>
<td>2. Sleep duration (h)</td>
<td>2. Variables measured with Achievement Goal Theory</td>
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<td></td>
<td></td>
<td>3. Variables measured with Sleep Study Survey</td>
</tr>
<tr>
<td>H3</td>
<td>1. Time using LED light technology before bed (h)</td>
<td>1. Variables measured with Motivated Strategies for Learning Questionnaire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Variables measured with Achievement Goal Theory</td>
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</tbody>
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Two statistical techniques could potentially be used to test the stated hypotheses: (a) correlation and multiple regression analysis, which are classical first-generation methods, developed nearly 100 years ago; however, these methods are currently considered to be obsolete by some statisticians (Kline, 2013) or (b) path analysis, which is a component of structural equation modeling (SEM). SEM is a modern second generation method, developed in the last twenty years, with many advantages over classical first generation methods (Kline, 2013; Hair, Hult, Ringle, & Starsted, 2014; Alavifar, Karimimalayer, & Annuar, 2012). Path analysis estimates the magnitude and significance of the partial correlations between sets of variables symbolized by arrows in a path diagram. SEM is a more complex approach which combines factor analysis with path analysis.

Bivariate correlation analysis (e.g., using Pearson’s $r$ coefficients) was not applicable to analyze the data collected in this study. Bivariate correlation coefficients were not computed because they are arguably the most misused and misleading statistics that have ever been devised (Burns, 1997; Ward, 2013). There are many arguments in the literature suggesting that correlation coefficients and other simple inferential statistics should be discontinued, or reduced in importance in behavioral research (Kline, 2013). The reasons why bivariate correlation coefficients were not computed in this study are as follows. First, a bivariate correlation coefficient only measures the strength of the association between two variables, without taking into account their joint or partial correlations with other variables. Bivariate correlation analysis is therefore only justified
if the data set being analyzed contains only two variables. If the data set contains multiple variables then a correlation matrix must be constructed to analyze the bivariate correlations between each pair of variables. However, when analyzing a matrix of bivariate correlations, a significant correlation between a pair of variables is often caused by their joint or partial correlation with a third controlling variable. Due to the effects of controlling variables, the bivariate correlations between one pair of variables in a correlation matrix are often spurious, and no logical inferences can be made. There are many examples of spurious correlations in the literature, for example, the significant positive correlation between the shoe size and the reading ability of junior school children (Burns, 1997). Does this positive correlation imply that having large feet makes children read better? Or does it imply that if children have a good reading ability then they will also grow large feet? These interpretations are clearly spurious. The reason why the correlation between foot size and reading ability among junior school children is spurious, is that both foot size and reading ability are positively correlated with a third variable, specifically the age of the children, which controls both the physical and cognitive growth of children. When examining the correlations between multiple variables, it is essential to exclude or partial out the all of the joint correlations with controlling variables and only interpret the partial correlations (Walczek, 1996).

Second, when interpreting the statistical significance of bivariate correlation coefficients in a correlation matrix, it is necessary to take Type I errors into account (i.e., the false declaration of a statistically significant correlation (conventionally, using the $p < .05$ criterion) by random chance, when, in fact, there is actually no significant correlation). The maximum probability of a Type I error using the conventional .05 level
of statistical significance is \(1 - (1 - 0.05)^k\) where \(k\) = the number of correlation coefficients used in the correlation matrix (Hair, Anderson, Babin, Tatman, & Black, 2010). The application of this formula means that if the correlation coefficients between seven variables are analyzed to test one hypothesis (as required in the current study) then the probability of a Type I error is \(1 - (1 - 0.05)^7 = 0.30\). Consequently, almost one third (i.e., two) of the seven correlations may not actually be statistically significant, with serious implications for the misleading and possibly meaningless interpretation of the results.

The procedures described by Duffy (2010) are salutary to illustrate the mistakes caused by Type I errors when interpreting the results of a bivariate correlation analysis. Duffy constructed a matrix of variables in an MS Excel worksheet, using random numbers generated with the RAND() function. Pearson’s correlation analysis was conducted to determine how many of the correlations between selected pairs of random variables were statistically significant at \(p < .05\). Duffy revealed considerable insight into the mistakes caused by Type I errors in a correlation matrix because many of the correlations were statistically significant, even though the variables computed using the RAND() function were entirely meaningless.

Multiple linear regression analysis is an improvement over bivariate correlation analysis, because partial regression coefficients take into account the effects of controlling variables. Multiple regression analysis was not, however, used in this study because the data were found to violate its strict theoretical assumptions (Chatterjee, Hadi, & Price, 2007) including: (a) the predictor variables were collinear (i.e., correlated with each other); (b) the residuals (i.e., differences between the observed and predicted values)
were not normally distributed; and (c) the residual error were not homogeneous across
the predicted values.

Path analysis by computation of partial least squares (PLS) was chosen to test the
stated hypotheses. The reason for using PLS was that this method has many advantages
over multiple regression, which is based on the computation of ordinary least squares
(OLS). These advantages mean that PLS is hailed as “indeed a silver bullet” (Hair et al.,
2011). The advantages described by Hair et al. (2014) are as follows: (a) PLS achieves
high levels of statistical power with small sample sizes; (b) PLS is a non-parametric
method, meaning that it not sensitive to the measurement or distributional characteristics
of the data; (c) PLS operates effectively with nominal, interval, and ordinal level
variables, irrespective of whether or not they are normally distributed; (d) all of the
variables are automatically standardized (by transforming to Z scores) before the
analysis; (e) PLS does not use goodness of criteria, because it does not fit a linear model
to the data by extracting information from the correlation/covariance matrix; (f) PLS
operates by optimizing the explained variance between the variables; (g) PLS uses a
bootstrapping algorithm, based on the Monte Carlo method, whereby 5000 random
samples are drawn from the data set, with replacement, to estimate the model statistics.

The variables used for the path analysis in this study were imported from IBM
SPSS v 20.4 into SmartPLS v. 2.0 software using a CSV (comma delimited) file. The
reason for using SmartPLS is that it is one of the most used software packages for
conducting analysis of survey data using PLS (Wong, 2013). The path coefficients (β)
and the effect sizes (R²) computed by Smart PLS were interpreted to provide the
statistical evidence to test the stated hypotheses. The β coefficients measured the strength
and direction of the partial correlations between the variables, and could potentially range from -1 to +1. The statistical significance of the β coefficients was indicated by the results of t-tests. A β coefficient was significantly different from zero if \( p < .05 \) for the t-test statistic, providing the statistical evidence to support a research hypothesis. \( R^2 \) indicated the proportion of the variance explained, and could potentially range from 0% to 100%.

In this study, a primary benefit of using PLS-SEM is that it can use an exploratory approach to search all available data, searching for variables that are significantly correlated with each other, and not just answer research questions and test hypotheses. Hair et al. (2017) emphasized that PLS-SEM is not only a confirmatory method (i.e., to answer research questions and test hypotheses based on deductive reasoning) but is also an exploratory method (i.e., to explore the data, in order to ask new research questions and generate new hypotheses, based on inductive reasoning). Therefore, using the exploratory approach PLS-SEM for the data analysis in this study is entirely appropriate if the confirmatory approach fails to provide significant results. This is because the exploratory approach often provides meaningful results that the researcher did not expect (Riou et al., 2015).

**Data Benefits**

Pilot study data were previously gathered for this study which allowed for revisions of the survey questions. The revisions captured more descriptive and factual information from this unique population, which aided in more valid and reliable research findings. This data also considered a very distinctive and innovative component, LED light technology, which has become a very prevalent issue, though it only specifically
relates to learning for this study. However, findings are beneficial to an array of fields, and simultaneously will enhance greater interdisciplinary cooperation with future research. This data will encourage academic institutions, parents, educators, and even students to take greater consideration about the influences and/or reasons for decreased academic progress, knowledge acquisition and acquisition. There has become a growing focus within society and among practitioners, psychologists, and physicians that medication(s) are the solution to enhance student focus and success. The research findings from this study should provide greater insight about other simplistic and natural alterations that can be done to improve student motivation, achievement, and engagement.

**Data Limitations**

The first data limitation is the participants in the survey were students who volunteered to participate, and so a convenience sample, and not a random sample, was used. Because random sampling was not used, the data may not be representative of the undergraduate population in the university as a whole. Sampling bias may have distorted the data because students who volunteer to participate in a survey may provide different answers to students who do not participate (Fraenkel & Wallen, 2010).

The second data limitation is that the self-reported data were biased, because the respondents provided responses that distorted the truth. There are at least 48 forms of bias associated with the collection of self-reported data (Choi & Pak, 2005). Socially desirable responding is a frequent source of bias in surveys (Mortell Van De, 2008). Social desirability bias is caused by respondents who fake or distort the answers to questionnaires by overestimating the behaviors that they perceive to be desirable (e.g.,
getting enough sleep) but underestimating the behaviors that they perceive to be undesirable (e.g. not getting enough sleep). Recall bias is another frequent source of error in self-report surveys, caused by the inability of respondents to accurately remember past experiences, particularly if they are asked to provide exact numbers. Because they are unable to recall them accurately, the respondents provide inaccurate numbers. For example, Lauderdale, Knutson, Yan, Liu, & Rathous (2008) compared self-reported measures of sleep duration with objective measures of sleep duration in the same individuals. This study concluded that most of the self-reported measures were inaccurate. There was only a very low correlation between the self-reported measures and the objective measures.

The next data limitation is the very crude comparison of the mean scores computed for the variables collected in this study vs. the mean scores for the same variables computed by the developers of the instruments. This limitation was because the developers’ surveys were not norm-referenced, meaning that their data were not collected using a random sample that was representative of the undergraduate student population in the country. The developers of the instruments only used convenience samples, which were not necessarily representative of the population from which they were drawn. Consequently, the mean scores computed by the developers of the instruments were not population norms. A comparison of the mean scores between two convenience samples does not provide any concrete information to evaluate the extent to which the mean scores are above or below the population norm, but is rather an interesting examination. (Kaplan & Saccuzzo, 2013). The computation of $t$-test statistics and $p$-values to compare mean values between two groups of students assumes random sampling. When students
are not randomly selected from the population in educational settings in order to compare mean scores between different groups, then $p$-values are only a very crude and inaccurate estimate of statistical significance (Fraenkel & Wallen, 2010).

The final data limitation of this study is that the results of the path analysis could not in any way be interpreted to prove the existence of causal relationships between sleep duration, time to sleep, use of LED technology, and academic achievement. The models constructed using PLS were only retrospective descriptions of the relationships between the variables, and the $\beta$ coefficients and $R^2$ values based on the analysis of survey data, and they did not imply causality. In order to analyze causal relationships, an experimental research design is required, in which one or more independent causal factors are prospectively manipulated in order to determine the subsequent effects on one or more dependent variables (Collier, Sekon, & Stark, 2010; Ward, 2013). The adage that “correlation does not imply causation” (Pearl, 2009, p. 96) applies directly to this study. This important issue is further considered in the Recommendations for Future Research section in Chapter Five: Discussion.
Chapter Four

Results

The purpose of this quantitative study was to examine the relationships between college student self-reports of pre-sleep technology usage, sleep patterns and behavior, and existing scales of academic achievement. This chapter presents the results of an analysis of the responses to the survey. The first section summarizes the demographic and contextual characteristics of the participants. The next sections provide the descriptive statistics for the variables measured in the survey. The subsequent sections present the statistical evidence to address the three research questions by testing the three stated hypotheses.

Characteristics of Participants

A total of $N = 151$ students volunteered to participate in the survey. The frequencies of the demographic categories of the participants are summarized in Table 3. The majority ($n = 120, 79.5\%$) were female. They reported that their age ranged from 18 to 46 years with an average age of 20.35 years. The most frequent age group ($n = 99, 66.5\%$) was 18 to 20 years. The dominant ethnic group was White ($n = 141, 93.4\%$). Most of the students were enrolled in the College of Nursing ($n = 51, 33.8\%$); the College of Education, Criminal Justice, and Human Services ($n = 45, 29.8\%$) or the College of Arts and Science ($n = 24, 15.9\%$). The most frequent majors were: Nursing ($n = 53, 35.1\%$); Education ($n = 27, 15.9\%$); Early Childhood ($n = 21, 13.9\%$); and Communications ($n = 19, 12.6\%$). Table 4 summarizes the contextual characteristics of the respondents.
Table 4

Demographic Characteristics of Participants (N = 151)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>120</td>
<td>79.5</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>31</td>
<td>20.5</td>
</tr>
<tr>
<td>Age (Years)</td>
<td>18-20</td>
<td>99</td>
<td>66.5</td>
</tr>
<tr>
<td></td>
<td>21-25</td>
<td>43</td>
<td>28.5</td>
</tr>
<tr>
<td></td>
<td>&gt; 25</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>No age reported</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>White</td>
<td>141</td>
<td>93.4</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Pacific-Islander</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>College</td>
<td>Nursing</td>
<td>51</td>
<td>33.8</td>
</tr>
<tr>
<td></td>
<td>Education, Criminal Justice, &amp; Human Services</td>
<td>45</td>
<td>29.8</td>
</tr>
<tr>
<td></td>
<td>Arts &amp; Sciences</td>
<td>24</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>Allied Health Sciences</td>
<td>21</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>Business, Music, Architecture</td>
<td>4</td>
<td>5.3</td>
</tr>
<tr>
<td>Major</td>
<td>Nursing</td>
<td>53</td>
<td>35.1</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>27</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>Early Childhood</td>
<td>21</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>Communications</td>
<td>19</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>Psychology, Speech Pathology</td>
<td>4</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Accounting, Health Sciences</td>
<td>4</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Science, Animal Biology, Biomed Science</td>
<td>3</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Fashion, Food &amp; Nutrition, Music</td>
<td>3</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>International Affairs, Marketing, Management</td>
<td>3</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>History</td>
<td>3</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Table 5

Contextual Characteristics of Participants (N = 151)

<table>
<thead>
<tr>
<th>Number of room-mates</th>
<th>0</th>
<th>31</th>
<th>20.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>39</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>44</td>
<td>29.1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Darkness of Sleep Space</th>
<th>Not at all dark</th>
<th>0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Somewhat dark</td>
<td>46</td>
<td>30.5</td>
</tr>
<tr>
<td></td>
<td>Dark</td>
<td>81</td>
<td>53.6</td>
</tr>
<tr>
<td></td>
<td>Very dark</td>
<td>24</td>
<td>15.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quietness of Sleep Space</th>
<th>Not at all quiet</th>
<th>4</th>
<th>2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Somewhat quiet</td>
<td>54</td>
<td>35.8</td>
</tr>
<tr>
<td></td>
<td>Quiet</td>
<td>73</td>
<td>48.3</td>
</tr>
<tr>
<td></td>
<td>Very quiet</td>
<td>20</td>
<td>13.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Credit hours in Spring 2017 semester</th>
<th>5-10</th>
<th>8</th>
<th>5.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11-16</td>
<td>103</td>
<td>68.2</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>37</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>21-25</td>
<td>2</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current cumulative GPA</th>
<th>1.0-1.5</th>
<th>1</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.6-2.0</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2.1-2.5</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>2.6-3.0</td>
<td>20</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>3.1-3.5</td>
<td>64</td>
<td>42.4</td>
</tr>
<tr>
<td></td>
<td>3.6-4.0</td>
<td>57</td>
<td>37.7</td>
</tr>
</tbody>
</table>

The participants reported that they lived with up to five room-mates. The most frequent number of room-mates (n = 44, 29.1%) was three. Over half of the participants (n = 81, 53.6%) slept in a dark space, and about one half of the participants (n = 74, 48.3%) slept in a quiet space. The students’ number of credit hours in the Spring 2017 semester ranged from 6 to 22. The most frequent number of credit hours was 11 to 16 (n = 103, 68.2%) with an average of 15.13 hours. The students’ cumulative GPA ranged
from 1.4 to 4.0 with an average of 3.36. The most frequent cumulative GPA was 3.1 to 3.5 ($n = 64, 42.4\%$).

**Descriptive and Comparative Analysis**

The following sections provide the results of a descriptive and comparative analysis of the variables operationalized using the Sleep Study Survey, the Epworth Sleepiness Scale, the Motivated and Learning Strategies Questionnaire, and the Achievement Goal Theory Framework.

**Sleep Study Survey**

The responses to the Sleep Study Survey are summarized in Table 6. The $K-S$ tests indicated that only four of the variables measured using this survey were normally distributed ($p > .01$). The four normally distributed variables (measured in hours) were Time in class ($M = 14.03$, $SD = 5.22$) which was similar to Time outside class ($M = 14.12$, $SD = 5.63$) and the responses to the Focus Test. The Focus Test required the students to respond to the question “Place an X under the appropriate column to indicate your level of focus DURING CLASSES this past week” and Place an X under the appropriate column to indicate your level of focus OUTSIDE OF CLASSES this past week”. The response format was a 6-point scale, defined by 1 = Extremely unfocused; 2 = Very unfocused; 3 = Somewhat unfocused; 4 = Somewhat focused; 5 = Very focused; and 6 = Extremely focused. The summary statistics indicated that the students were, on average, somewhat focused during classes ($M = 4.05$, $SD = 1.35$). Similarly, the students were, on average, somewhat focused outside classes ($M = 4.12$, $SD = 1.49$).
Table 6

Descriptive Statistics and Normality Tests of Variables Measured with Sleep Study Survey (N = 151)

<table>
<thead>
<tr>
<th>Construct</th>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Mdn</th>
<th>K-S test (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>School work (per week)</td>
<td>Exams, quizzes, assignments, and tests</td>
<td>3.33</td>
<td>2.04</td>
<td>2.87</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Time in class (h)</td>
<td>14.03</td>
<td>5.22</td>
<td>14.10</td>
<td>.160</td>
</tr>
<tr>
<td></td>
<td>Time outside class (h)</td>
<td>14.12</td>
<td>5.63</td>
<td>14.07</td>
<td>.709</td>
</tr>
<tr>
<td>Focus test</td>
<td>Level of focus during classes</td>
<td>4.05</td>
<td>1.35</td>
<td>3.17</td>
<td>.892</td>
</tr>
<tr>
<td></td>
<td>Level of focus outside classes</td>
<td>4.12</td>
<td>1.49</td>
<td>2.99</td>
<td>.543</td>
</tr>
<tr>
<td>Sleeping behavior (h/day)</td>
<td>Time napping (during day)</td>
<td>0.37</td>
<td>0.54</td>
<td>0.19</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Sleep duration (at night)</td>
<td>7.01</td>
<td>0.82</td>
<td>6.91</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Ideal length of time to sleep at night</td>
<td>7.56</td>
<td>1.31</td>
<td>7.67</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Time to fall asleep (at night)</td>
<td>0.39</td>
<td>0.35</td>
<td>0.27</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Frequency of sleep</td>
<td>Phone calls</td>
<td>0.12</td>
<td>0.33</td>
<td>0.12</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>interruptions (per night)</td>
<td>Social media/app notifications</td>
<td>0.16</td>
<td>0.72</td>
<td>0.07</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Startling noises</td>
<td>0.87</td>
<td>1.36</td>
<td>0.49</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Text message/emails</td>
<td>0.45</td>
<td>1.13</td>
<td>0.25</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Television noise</td>
<td>0.01</td>
<td>0.08</td>
<td>0.01</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1.43</td>
<td>2.07</td>
<td>0.67</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Using restroom</td>
<td>1.19</td>
<td>1.84</td>
<td>0.63</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Time using LED light</td>
<td>All devices</td>
<td>1.35</td>
<td>1.34</td>
<td>0.98</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>before bed (h/day)</td>
<td>Computer</td>
<td>0.002</td>
<td>0.015</td>
<td>0.001</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Cellphone</td>
<td>0.66</td>
<td>0.77</td>
<td>0.45</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Laptop</td>
<td>0.45</td>
<td>0.82</td>
<td>0.03</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>Tablet</td>
<td>0.07</td>
<td>0.28</td>
<td>0.01</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td></td>
<td>TV</td>
<td>0.17</td>
<td>0.42</td>
<td>0.02</td>
<td>&lt;.001*</td>
</tr>
</tbody>
</table>

Note: Significant deviation from normality (p < .01)

The other 18 variables measured using the Sleep Study Survey deviated strongly from normality (p < .001 for the K-S test). The frequency distribution histograms of the variables illustrated in Figure 2 illustrate how the variables deviated from normality, because their frequency distributions were asymmetrical. The modes (highest frequencies) were not at the centers of the distributions, reflecting normality, but were located at the lower ends of the measurement scales.
Figure 2. Frequency distribution histograms of sleeping behaviors and LED usage

The modes indicated that (a) 91.39% of the students reported that they spent less than 1 h napping during the day; (b) 51.04% slept for less than 7 h at night; (c) 85.43% took less than one hour to go to sleep; and (d) 43.05% used LED technology for less than 1 h before bed. The tails on the right-hand sides of the histograms indicated that (a) 8.61% of the students reported that they spent 1 to 3 h napping during the day; (b) 49.23% slept for more than 7 h at night; (c) 15.47% took 1 to 2 h to go to sleep; and (d) 56.95% used LED technology for more than 1 h before bed.

Because the distributions deviated from normality, the median, rather than the mean, was used to summarize these variables. The median frequency of exams, quizzes, assignments, and tests per week was 2.87. The median time per day spent napping was 0.19 h. The reported time that the participants slept at night (Mdn = 6.91 h) was less than the participants perceived was the ideal length of time to sleep at night (Mdn = 7.67 h).
hours). The median time to fall asleep was 0.27 h. The most frequent sleep interruptions were caused by other things (Mdn = 0.67); using the restroom (Mdn = 0.63); and startling noises (Mdn = 0.49). The least frequent sleep interruptions were caused by text messages/emails (Mdn = 0.25); phone calls (Mdn = 0.12); social media/app notifications (Mdn = 0.07); and television (Mdn = 0.01).

The median time using all devices with LED light technology before bed was 1.34 h/day. Before bed, the most time spent with devices was with cellphones (Mdn = 0.66 h/day) and laptops (Mdn = 0.82 h/day). Less time was spent watching TV (Mdn = 0.17 h/day) using tablets (Mdn = 0.07 h/day) and computers (Mdn = 0.002 h/day).

**Epworth Sleepiness Scale**

Figure 3 displays a frequency distribution histogram of the total scores for the Epworth Sleepiness Scale.
The frequency distribution of the Epworth Sleepiness Scale did not deviate strongly from normality \((p > .01\) for the \(K-S\) test). The maximum possible range of scores for the scale was 0 to 24, where 0–10 = range of daytime sleepiness for healthy adults; 11–14 = mild sleepiness; 15–17 = moderate sleepiness; 18 or higher = severe sleepiness (Johns, 2009). In comparison, the scores for the Epworth Sleepiness Scale measured in this study ranged from a minimum of 5 to a maximum of 14. The majority of the participants \((n = 107, 70.86\%)\) scored between 5 and 10, which was within the expected range of sleepiness during the day for healthy adults. The remainder \((n = 44, 29.14\%)\) scored between 10 and 14, which reflected mild sleepiness during the day. None of the participants suffered from severe sleepiness. Table 7 presents a statistical analysis of the Epworth Sleepiness Scale. The mean score measured in this study was less than 10 \((M = 9.33, SD = 1.09)\), indicating that on average, most of the participants experienced a normal healthy level of daytime sleepiness.

Table 7

<table>
<thead>
<tr>
<th>Variable</th>
<th>This study ((N = 151))</th>
<th>Johns (1992) ((N = 104))</th>
<th>M Difference</th>
<th>Independent samples t-test assuming unequal variances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epworth Sleepiness Scale</td>
<td>9.33 1.09</td>
<td>7.6 3.9</td>
<td>1.8</td>
<td>4.41 &lt;.001*</td>
</tr>
</tbody>
</table>

Note: * Significant difference \((p < .001)\)

The mean score for the Epworth Sleepiness Scale collected from the convenience sample of undergraduate students who participated in this study was compared against the mean score collected from the convenience sample of medical students reported by the developer of the instrument (Johns, 1992). The mean score obtained in this study was
greater by 1.73 than in the developer’s study. The standard deviation (SD = 1.09) was lower than in the developer’s study. An independent samples \( t \)-test assuming unequal variances was conducted. The difference between the mean scores in the two studies was statistically significant \( (p < .001) \).

Figure 4 presents a visual examination of the relationships between the Epworth Sleepiness Scale, the Time Napping in Day, the Sleep Duration at Night, and the Time to Fall Asleep (h) using scatterplots fitted with linear trend lines.

Figure 4. Plots of Epworth Sleepiness Scale vs. Time Napping in Day, Sleep Duration at Night, and Time to Fall Asleep

The approximately horizontal trend lines indicate that the Epworth Sleepiness Scale did not appear to increase or decrease systematically with respect to Time Napping in Day or Time to Fall Asleep. The downward sloping trend line indicated that students who felt excessively sleepy during the day (with a score of > 10 for the Epworth
Sleepiness Scale) tended to sleep for a shorter time at night (about 5 to 6 hours). In contrast, students who fell within the healthy level of sleepiness during the day (with a score of < 10 for the Epworth Sleepiness Scale) tended to sleep for a longer time at night (6 to 9 hours).

**Motivated Strategies for Learning**

The four variables measured with the Motivated Strategies for Learning Questionnaire, using a 6-point scale, where 1 = the minimum and 6 = the maximum, did not strongly deviate from normality ($p > .01$ for the $K-S$ tests). The statistics for the four variables are presented in Table 8.

Table 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>This study $(N = 151)$</th>
<th>Pintrich et al. $(N = 356)$</th>
<th>Mean Difference</th>
<th>Independent samples t-test assuming unequal variances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort regulation</td>
<td>5.40 0.71</td>
<td>5.25 1.10</td>
<td>0.15</td>
<td>1.83 .068</td>
</tr>
<tr>
<td>Extrinsic goal orientation</td>
<td>4.92 0.48</td>
<td>5.03 1.23</td>
<td>-0.11</td>
<td>-1.45 .148</td>
</tr>
<tr>
<td>Self-efficacy for learning/achievement</td>
<td>4.74 0.78</td>
<td>5.47 1.14</td>
<td>-0.73</td>
<td>8.33 &lt;.001*</td>
</tr>
<tr>
<td>Intrinsic goal orientation</td>
<td>4.33 0.95</td>
<td>5.03 1.09</td>
<td>-0.70</td>
<td>7.25 &lt;.001*</td>
</tr>
</tbody>
</table>

Note: * Significant difference ($p < .001$).

The highest mean scores were for Effort regulation ($M = 5.40$) and Extrinsic goal orientation ($M = 4.92$). The lowest mean scores were for Intrinsic goal motivation ($M = 4.33$) and Self-efficacy for learning achievement ($M = 4.74$). The standard deviations ($SD = 1.09$ to 1.23) computed by the developers of the instrument (Pintrich et al., 1993) were
consistently greater than the standards deviations computed in this study ($SD = 0.48$ to $0.95$). The results of independent samples $t$-tests assuming unequal variances indicated that the mean scores for Self-efficacy for learning/achievement, and Intrinsic goal orientation were significantly different between the two studies ($p < .001$). However, the mean scores for Effort regulation ($p = .068$) and Extrinsic goal orientation ($p = .148$) were not significantly different.

**Achievement Goal Theory**

Table 9 presents the results of the analysis of the variables measured with the Achievement Goals Framework, using a 7-point scale, where 1 = the minimum level and 7 = the maximum level of achievement goals. These five variables did not strongly deviate from normality ($p > .01$ for the K-S tests). The highest scores were for Other-approach goals ($M = 5.54$); Self-avoidance goals ($M = 5.50$); Other-avoidance goals ($M = 5.49$) and Task-approach goals ($M = 5.47$). The lowest scores were for Self-approach goals ($M = 5.39$) and Task-avoidance goals ($M = 5.34$). The standard deviations ($SD = 0.83$ to $1.41$) computed by the developers of the instrument (Elliott & Peckrum, 2011) were consistently greater than the standards deviations computed in this study ($SD = 0.60$ to $0.82$). The results of independent samples $t$-tests assuming unequal variances to compare the two sets of scores indicated that the mean scores computed for this study and by the developers of the instrument were all significantly different ($p < .05$).

Table 9

<table>
<thead>
<tr>
<th>Variable</th>
<th>This study ($N = 151$)</th>
<th>Elliot &amp; Peckrum (2011) ($N = 319$)</th>
<th>Mean difference</th>
<th>Independent samples $t$-test $t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other-approach goals</td>
<td>5.54</td>
<td>4.99</td>
<td>1.41</td>
<td>5.87</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Goal Type</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>------------------------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Self-avoidance goals</td>
<td>5.50</td>
<td>0.60</td>
<td>5.67</td>
<td>1.24</td>
<td>-0.17</td>
</tr>
<tr>
<td>Other-avoidance goals</td>
<td>5.49</td>
<td>0.71</td>
<td>5.17</td>
<td>1.37</td>
<td>0.32</td>
</tr>
<tr>
<td>Task-approach goals</td>
<td>5.47</td>
<td>0.64</td>
<td>6.28</td>
<td>0.83</td>
<td>-0.81</td>
</tr>
<tr>
<td>Self-approach goals</td>
<td>5.39</td>
<td>0.75</td>
<td>5.71</td>
<td>1.19</td>
<td>-0.32</td>
</tr>
<tr>
<td>Task-avoidance goals</td>
<td>5.34</td>
<td>0.82</td>
<td>5.90</td>
<td>1.09</td>
<td>-0.56</td>
</tr>
</tbody>
</table>

Note: * Significant difference (p < .05)

**Use of LED Technology and Sleeping Behavior**

This section addresses RQ1: What are the relationships between usage of LED light technology before bed, time to fall asleep and total sleep duration? Statistical evidence is presented to test H1: Students who report high usage of LED light technology before bed will also report a long time to fall asleep and a short total sleep duration. The scatterplots fitted with linear trend lines in Figure 5 provide a visual indication to support H1, because sleep duration tended to decrease when use of led increased, whereas time to fall asleep tended to increase when use of led increased. The path diagram constructed by SmartPLS to test H1 is illustrated in Figure 6. The three variables in Figure 6, represented by oval symbols, were measured in h/day using the responses to the Sleep Study Survey. The time of Use of LED technology before bed (h) was operationalized by adding up all the reported times for the use of other devices, computers, cellphones, laptops, and TV before bed.
Figure 5. Plots of Sleep Duration and Time to Fall Asleep vs. Use of LED

Figure 6. Path analysis of relationships between use of LED technology and sleeping behavior

The first path represented by an arrow in Figure 6 indicated that the total time that the participants used various types of LED light technology was significantly and positively correlated with the time taken by the participants to fall asleep ($\beta = 0.351, t = 3.39, p < .001$). The positive path coefficient indicated that students who reported
increased usage of LED light technology before bed also reported increased time falling asleep. The effect size ($R^2 = 0.123$) indicated that 12.3% of the variance in the time to fall asleep was explained by the time that LED light technology was used before bed.

The second path represented by an arrow in Figure 6 indicated that the total time that the students used various types of LED light technology before bed was significantly and negatively correlated with their sleep duration ($\beta = -0.149, t = 2.28, p = .023$). The effect size ($R^2 = 0.022$) indicated that 2.2% of the variance in the sleep duration of the participants was explained by the time they used LED light technology before bed. This significant negative path coefficient implied that students who spent a long time using LED devices before bed slept for a shorter duration than students who did not spend a long time using LED light technology before bed.

The results of the path analysis were consistent with H1, because college students who reported high usage of LED light technology before bed also reported a long time to fall asleep as well as a short total sleep duration. The statistical evidence implied that students who used more LED light technology before bed found it more difficult to go to sleep, and also to sleep for a long time. The effect size between Use of LED and Time to Fall Asleep (12.3%) was greater than the effect size between Use of LED and Sleep Duration (2.2%). The conclusion is that a longer time of use of LED light technology before bed may have a greater effect on increasing the students’ time to fall asleep than it does on decreasing their sleep duration.

**Academic Achievement and Sleeping Behavior**

This section addresses RQ2: What are the relationships between time to fall asleep, total sleep duration, and academic achievement? Statistical evidence is presented
to test H2: Students who report a long time to fall asleep will also report a short sleep duration, and low scores for academic achievement. Three models were constructed to test H2. The first model used the six variables measured with the Achievement Goal Theory (AGT) to represent academic achievement. The scatterplots in Figure 7 did not visually support H2 because no clear linear trends can be observed. The path diagram constructed by SmartPLS to test H2 is illustrated in Figure 8. The seven path coefficients were consistently very weak (β = -0.087 to 0.040). None of the path coefficients were significantly different from zero (t < 1.98; p > .05). The effect sizes (R² = 0.000 to .008) indicated that a very small proportion (less than 0.8%) of the variance in the six AGT variables was explained by Sleep Duration. Furthermore, Time to Fall Asleep and Sleep Duration were not significantly correlated. The conclusion is that the path model in Figure 8 did not support H2 because college students who reported a long time to fall asleep did not also report decreased sleep duration, nor did they report low academic achievement, represented by the AGT variables.
**Figure 7.** Plots of six AGT variables and Time to Fall Asleep vs. Sleep Duration

**Figure 8.** Path model of relationships between AGT variables and sleeping behavior
The second model to test H2 used the four variables measured with the Motivated Strategies for Learning Questionnaire (MSLQ) to represent academic achievement. The scatterplots in Figure 6 did not support H2 because there were no clear positive or negative linear trend lines between the four MSLQ variables and Sleep Duration. The path diagram constructed by SmartPLS to test H2, using the same data plotted in Figure 9.

![Scatter plots](image)

*Figure 9. Plots of four MSLQ variables vs. Sleep Duration*

The path coefficients were consistently very weak ($\beta = -0.075$ to $0.137$). None of the path coefficients were significantly different from zero ($t < 1.98; p > .05$). The effect sizes ($R^2 = 0.001$ to $0.019$) indicated that a very small proportion (less than 2 %) of the variance in the six AGT was explained by Sleep Duration. Furthermore, Time to Fall Asleep and Sleep Duration were not significantly correlated. The path model in Figure 10 did not support H2 because the students who reported a long time to fall asleep did not
also report decreased sleep duration, nor did they report a decreased level of academic achievement, indicated by the four MSLQ variables.

Figure 10. Path analysis of relationships between four MSLQ variables and sleeping behavior

The third model to test H2 used the two measurements of Focus (During Classes, and Outside Classes) measured with the Sleep Study Survey to represent academic achievement. The scatterplots fitted with linear trend lines in Figure 11 provide a visual indication to support H2, because Focus during and outside classes tended to increase linearly when Sleep Duration increased. The path diagram constructed by SmartPLS to test H2 is illustrated in Figure 12.
**Figure 11.** Plots of two Focus variables vs. Sleep Duration

![Plots of two Focus variables vs. Sleep Duration](image)

**Figure 12.** Path analysis of relationships between two Focus variables and sleeping behavior

The path model in Figure 12 provided further evidence that Time to Fall Asleep was not significantly related to Sleep Duration ($\beta = .004; t = 0.54, p = .589$). Sleep Duration was, however, significantly and positively correlated with Focus During Classes ($\beta = 0.781, t = 23.39, p < .001$). Sleep Duration was also significantly and positively correlated with Focus Outside Classes ($\beta = 0.680, t = 17.91, p < .001$).
The statistically significant positive path coefficients in Figure 11 indicated that students who had longer times of sleep duration also reported higher levels of focus during classes and outside classes. The effect sizes indicated that 60.9\% of the variance in Focus During Classes and 46.2\% of the variance in Focus Outside Classes was explained by Sleep Duration.

The path model in Figure 12 partially supported H2 because college students with short sleep duration, did not also report a low level of focus. The students reported an increase in focus during and outside classes when their sleep duration was longer. However, time to fall asleep and sleep duration were not correlated.

**Academic Achievement and Use of LED Technology**

This section addresses RQ3: What are the relationships between usage of LED technology and academic achievement? Statistical evidence is presented to test H3: Students who report a low usage of LED technology before bed will also report high scores for academic achievement. The first model to test H3 used the six variables measured with the AGT to represent academic achievement. The scatterplots in Figure 13 did not visually support H3 because no clear upward or downward sloping linear trends can be observed. The path model constructed by SmartPLS to test H3 is illustrated in Figure 14.
Figure 13. Plots of AGT variables vs. Use of LED

![Plots of AGT variables vs. Use of LED](image)

Figure 14. Path analysis of relationships between AGT variables and Use of LED

![Path analysis of relationships between AGT variables and Use of LED](image)

The seven path coefficients were consistently very weak ($\beta = -0.003$ to 0.172). None of the path coefficients were significantly different from zero ($t < 1.98; p > .05$). The effect sizes ($R^2 = 0.000$ to .029) indicated that a very small proportion (less than
2.9%) of the variance in the six AGT variables and Time to Fall Asleep was explained by Use of LED. The conclusion is that the path model in Figure 14 did not support H3 because college students who reported increased levels of academic achievement did not report decreased usage of LED light technology before bed.

The second model to test H3 used the four variables measured with the MSLQ to represent academic achievement. The scatterplots in Figure 15 did not visually support H3 because no clear linear upward or downward sloping trends can be observed. The path model constructed by SmartPLS to test H3 is illustrated in Figure 16.

![Scatterplots of MSLQ variables vs. Use of LED](image)

*Figure 15. Plots of MSLQ variables vs. Use of LED*

The four path coefficients in Figure 16 were consistently very weak (\(\beta = -0.126\) to 0.014). None of the path coefficients were significantly different from zero (\(t < 1.98; p > 0.05\)). The effect sizes (\(R^2 = 0.000\) to 0.016) indicated that a negligible proportion (≤ 1.6 %) of the variance in the four MSLQ variables was explained by Use of LED. The conclusion is that the path model in Figure 16 did not support H3 because college
students who reported increased levels of academic achievement did not report decreased usage of LED light technology before bed.

Figure 16. Path analysis of relationships between MSLQ variables and Use of LED

The third model to test H3 used the two measurements of Focus (During Classes, and Outside Classes) measured with the Sleep Study Survey to represent academic achievement. The scatterplots fitted with linear trend lines in Figure 17 provide a visual indication to support H3, because Focus during classes and outside classes tended to decrease linearly when Use of LED increased. The path model constructed by SmartPLS to test H3 is illustrated in Figure 18.
Figure 17. Plots of Focus variables vs. Use of LED

Figure 18. Path analysis of relationships between Focus variables and Use of LED

The two path coefficients in Figure 18 were significantly different from zero. Use of LED was negatively correlated with Focus During Classes ($\beta = -0.184$, $t = 4.23$, $p < .001$) and was also negatively correlated with Focus Outside Classes ($\beta = -0.217$, $t = 7.34$, $p < .001$). The negative path coefficients indicated that students who had longer
times of LED usage before bed also reported lower levels of focus, during and outside classes.

The effect sizes ($R^2 = .034$ and .047) indicated that 3.4% of the variance in Focus During Classes and 4.7% of the variance in Focus Outside Classes was explained by Use of LED. The conclusion is that the path model in Figure 18 supported H3 because college students who reported higher levels of focus during the day also reported lower usage of LED light technology before bed.

**Conclusions**

The conclusions based on the descriptive and comparative analysis of the variables collected with the Sleep Study Survey, MSLQ, AGT, and ESS are as follows. A total of $N = 151$ students volunteered to participate in the survey. The sample was not necessarily representative of the undergraduate population in the USA. The majority of the students were female. Their average age was 20.35 years. The dominant ethnic group was White. Most of the students were enrolled in nursing colleges, CECH, or Arts and Science colleges. The most frequent majors were Nursing and Education. The mean time the students spent in classes was similar to the mean time spent working outside classes. The students were, on average, somewhat focused during classes, and somewhat focused outside classes.

The median time using all devices with LED light technology before bed was 1.34 h/day. The median time to fall asleep was 0.27 h. The median time that the participants slept at night (6.91 h) was less than the participants perceived was the ideal length of time to sleep at night.
Before bed, the most time spent with devices was with cellphones and laptops. Less time was spent watching TV, using tablets, and computers before bed. The most frequent sleep interruptions were caused by other devices, using the restroom, and startling noises. The least frequent sleep interruptions were caused by text messages/emails, phone calls, social media/app notifications, and television.

The majority of the participants scored between 7 and 10 on the Epworth Sleepiness Scale, which was within the normal healthy range of sleepiness during the day for adults. The remainder of the students scored between 10 and 13, which reflected mild sleepiness during the day. None of the participants suffered from severe sleepiness during the day. The mean score for the Epworth Sleepiness Scale obtained in this study was significantly ($p < .001$) greater than that reported by the developer of the instrument (Johns, 1992). Students who had high scores (> 10) for this scale tended to sleep for a shorter time at night than students who had low scores (< 10).

The analysis of the responses to the Motivated Strategies for Learning Questionnaire indicated that the highest mean scores were for Effort regulation and Extrinsic goal orientation. The lowest mean scores were for Intrinsic goal motivation and Self-efficacy for learning achievement. The mean scores for Self-efficacy for learning/achievement, and Intrinsic goal orientation were significantly different ($p < .001$) between this study and the study conducted by the developer of the instrument (Pintrich et al., 1993). However, the mean scores for Effort regulation and Extrinsic goal orientation were not significantly different between the two studies.

The analysis of the responses to the Achievement Goals Framework indicated that the highest scores were for Other-approach goals, Self-avoidance goals, Other-avoidance
goals, and Task-approach goals. The lowest scores were for Self-approach goals and Task-avoidance goals. The mean scores for all the variables measured in this study were significantly different to the mean scores obtained by the developers of the instrument (Elliott & Peckrum, 2011). The final conclusions, based on the testing of the three stated hypotheses using path analysis, are summarized in Table 10.

Table 10

*Testing of Hypotheses based on Path Analysis*

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: Students who report high usage of LED light technology before bed will also report a long time to fall asleep and a short total sleep duration.</td>
<td>H1 was fully supported. Students who reported high usage of LED light technology before bed also reported a long time to fall asleep and a low total sleep duration. The time of use of LED light technology before bed had a significantly greater effect on increasing the students’ time to fall asleep than it did on their sleep duration.</td>
</tr>
<tr>
<td>H2: Students who report a long time to fall asleep will also report a short sleep duration, and low scores for academic achievement</td>
<td>H2 was only partially supported. The time to fall asleep and sleep duration were not correlated. Although students with low sleep duration, did not report low scores for the MSLQ or AGT, they did report higher scores for Focus during and outside classes when their sleep duration was long.</td>
</tr>
<tr>
<td>H3: Students who report a low usage of LED technology before bed will also report high scores for academic achievement.</td>
<td>H3 was only partially supported. Although the MSLQ and AGT variables were not correlated with usage of LED, students who reported high levels of Focus during and outside classes also reported low usage of LED light technology before bed.</td>
</tr>
</tbody>
</table>
Chapter Five

Discussion

This study was designed to explore how the usage of LED light technology before bedtime may influence sleep duration and academic achievement among college students. Specifically, the objective of this research was to investigate the ways in which the use of LED light technology (i.e., smart phones, tablets, laptops, and televisions) during bedtime hours suppresses melatonin onset (Chang, Aeschbach, Duffy, & Czeisler, 2015) by reawakening the brain (Lack, Partridge, & Wright, 2001), which impacts total sleep duration (Lemma, Berhane, Worku, Gelaye, & Williams, 2014) and directly or indirectly influences academic achievement (Perkinson-Gloor, Lemola, & Grob, 2013).

Data were collected through a self-developed sleep journal log that contained initial questions inquiring about sleeping habits and academic progress in addition to three existing measurement scales: Epworth Sleepiness Scale (Johns, 1992), the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993), and the 3x2 Achievement Goal Theory Model (Elliot, Murayama, & Pekrun, 2011) to further understand the effects from sleep deprivation on daytime sleepiness and academic achievement.

In this chapter, the discussion of findings will provide a comprehensive focus on greater explanation of the statistical relationships between college students’ self-reports of pre-sleep LED technology usage, sleep patterns and behavior, and academic achievement. Descriptive statistical findings will first be presented followed by a discussion of the relationship between the results and the three research questions. Next, the second section will express practical implications of the findings for undergraduates,
university educators, and administrators will be examined. Finally, comments related to the main limitations of this study, recommendations for future research, and conclusions will be presented.

Review and Discussion of the Main Conclusions

The following section provides the most noteworthy results from the sleep survey along with a discussion of the findings for each hypothesis. The discussion is concluded with an analysis of the implications of the findings, study limitations, and potential areas for future studies.

Sleep Survey Participant Characteristics

This study gathered descriptive information from a group of undergraduate students comprised primarily of nursing, education, and communication majors. In that a primary objective of this study was to explore college students sleep patterns, it was interesting that the students believed the ideal length of sleep needed for their age group was approximately 7.67 hours of sleep per night, but on average, were only sleeping 6.9 hours. This finding is substantially less than the eight to nine hours of sleep consistently recommended for adolescents and college students (Carskadon, Acebo, & Seifer, 2001; National Sleep Foundation, 2011). This suggestion is significant because increased sleep minimizes poor academic performance, slower reaction times, reduced cognitive thinking, and the selection of less demanding and less difficult tasks (Engle-Friedman et al., 2003).
Participants from this study averaged relatively high GPAs, but were not taking an excessive amount of credit hours either. It is possible that daily reported naps also enhanced academic achievement by reducing the negative effects of sleep deprivation since brief naps are an effective method to temporarily improve learning, increase performance, speed, and accuracy on tasks (Mednick, Nakayama, & Stickgold, 2003).

In the sleep survey, questions about participants’ sleep hygiene were incorporated to support previous research findings that greater knowledge about the specific factors influencing sleep practices provides more insight about sleep quality and sleep duration (Buboltz, Soper, Brown, & Jenskins, 2002). Among those components associated with sleep practices and bedtime environment included in this study were: darkness levels, quietness of sleep space, and number of roommates (Tsui & Wing, 2009). The most interesting finding reported by participants was having, on average, at least three roommates. Sexton-Radek and Hartley (2013) stated that the number of roommates’ taken in conjunction with sleep practices significantly contributes to sleep disturbances and decreased sleep duration for college students. Additional research exploring sleep environments (e.g., home, dorms, apartments) would highlight unique differences for each type (e.g. traditional vs. non-traditional) of college student, allowing for better living spaces across groups.

**Sleep Survey Findings about Academic Achievement**

Questions from the sleep survey that inquire about academic achievement pertain to students’ level of focus both during and outside of class, along with the variables from the Achievement Goal Theory model, and the variables from the Motivated Strategies for Learning Questionnaire. Significant results demonstrated that students were focused both
during class and outside of class, which compliments all four variables from the Achievement Goal Theory model that were significant: Other-approach goals, other-avoidance goals, self-avoidance goals, and task-approach goals. Students are driven to complete tasks correctly (task-approach goal), giving them an advantage to do better than on previous assessments (self-avoidance goal), with the hope of doing better than their classmates (other-approach goal) or at least trying to avoid doing worse than their peers (other-avoidance goal). Two of the goals are approach-based and two are avoidance-based signifying that participants maintain a balance of approaching success and/or avoiding failure towards their academic goals both during and outside of class by using the task, intrapersonal (self), or interpersonal (others) reasons as their motivation to remain focused (Elliot, Murayama, & Pekrun, 2011).

The development of the Motivated Strategies for Learning Questionnaire was grounded within the Achievement Goal Theory model. The AGT is based on assessment of students’ goals and values for a course, beliefs about their skills and/or abilities to succeed, extrinsic and intrinsic drive to sustain attention and focus, along with learning strategies to accomplish those goals (Duncan & McKeachie, 2005). Therefore, significance found among variables within the MSLQ in this study aids in greater explanation about the significance found among the AGT findings along with students being focused both during and outside of classes.

Among participants, effort regulation scored the highest of all the MSLQ components. This finding coincides with focus because it implies that college students can self-regulate their own progress when they remain concentrated on achieving goals by controlling their attention and effort despite distractions or uninteresting tasks. Self-
efficacy for learning and performance was found to be a slightly less significant MSLQ component in this study; however, this finding is still relevant to focus because it signifies that students practice self-efficacy as an agent in self-motivation, intrinsic drive, and concentration (Zimmerman & Bandura, 1994; Zimmerman & Risemberg, 1997). Interestingly, studies have found that effort regulation was a primary mediator between self-efficacy and academic achievement with more self-efficacious students achieving greater academic gains because they can better self-regulate their attention and focus as needed (Komarraju & Nadler, 2013). Self-efficacy is also an evident factor within intrinsic motivation and extrinsic motivation, which were also significant MSLQ components in this study, as research has found fluctuations across a semester in students’ effort level and performance based on their confidence and value for learning (Zusho & Pintrinch, 2003). Self-efficacy is possibly a fundamental aspect in academic achievement and focus because indirect connections have been linked between goal setting and effort regulation to maintain persistence when encountering uninteresting or difficult academic tasks (Bandura, 1997; Pintrich, 1999; 2000).

**Sleep Survey Findings about Sleep and LED Technology**

Results from the Epworth Sleepiness Scale found that most students scored within the normal range for daytime sleepiness; however, a small portion of participants scored in the range for mild sleepiness. Studies have shown that even scores in the lower range of the Epworth Sleepiness Scale were associated with decreased grades, late assignments, reduced energy for academic activities, along with sleepiness and a lack of focus at school (Gibson et al., 2006). Students who fell within the range of mild daytime sleepiness also reported the shortest amount of evening sleep and increased daytime naps,
which parallels previous research stating that even a single night of sleep loss can induce daytime micro-sleeps from sleepiness. Micro-sleeps have been linked to poor school performance and academic achievement, with on-going sleep loss leading to excessive daytime sleepiness (Millman, 2005).

Use of LED technology before bedtime increased total time to fall asleep, with students reporting the greatest use of cellphones and laptops. Results found that students spent over an hour using all devices with LED technology which is consistent with the National Sleep Foundation’s findings (2011) that within one hour prior to bedtime Generation Y demonstrates some of the heaviest usage of technological devices with smartphones and laptops being the frontrunners for most used products. In this study, participants reported, on average, taking just under an hour to fall asleep. This is consistent with Wood, Rea, Plitnick, and Figueiro (2013) who found that just one hour of exposure to LED blue light technology that is positioned at least 9.7 inches from an individuals’ face can significantly suppress melatonin onset.

Results further indicated that once asleep, the primary sleep interruptions occur from other incidences (e.g., roommates, light, nightmares), use of the restroom, and startling noises. Previous research has addressed that REM sleep is required for memory consolidation, memory formation, and strengthening of neural connections to enhance learning (Blumberg, 2010). REM sleep is also a “deep sleep stage” which the body must enter to ever fully rest and recover, preventing daytime sleepiness or excessive fatigue (Alhola & Polo-Kantola, 2007; Silkis, 2010). REM sleep increases in duration throughout the night with the maximum level of information processing, memory consolidation, cell repair and growth occurring in the last quartile before awakening. Therefore, any sleep
disruptions that prevent an individual from entering REM sleep and/or reaching the optimal level needed for learning and full recovery will negatively affect learning and daytime sleepiness (Stickgold et al., 2000).

**Comparison of Findings Among Measurement Scales**

The comparison of standard deviations between the findings in this study to the original developers’ findings of each measurement scale were all significantly lower. Initially, this idea may appear to support greater generalizability of the results, but such a comparison is illogical because the convenience sample used in this study was not drawn from the same population as the convenience samples used by the developers of each instrument. If convenience samples are drawn from two entirely different populations, at varying times and locations, and using different sample sizes, then a t-test will inevitably indicate that the mean scores for each population will be significantly different. To determine if the results of this study are externally valid, it would be necessary to compare the mean scores obtained in this study with the mean scores obtained using norm referenced random samples drawn from the same population; however, the developers of the measurement scale did not use norm referenced random samples from the same population.

**LED Technology and Sleeping Behavior – Hypothesis 1**

The first hypothesis contended that students who report high usage of LED light technology before bed will also report a long time to fall asleep and a short total sleep duration.
Conclusions

The first hypothesis was fully supported by the duration of time spent using LED light technology before bedtime increasing the total time to fall asleep. However, only partial support was shown for the duration of time spent using LED light technology before bedtime and total duration of sleep, implying that shorter sleep duration was influenced by longer total time spent using LED devices before bed.

Results were consistent with the first hypothesis because students who used various forms of LED light technology for an extended period of time before bed had difficulty falling asleep and experienced a shorter length of total sleep. The current study extended the findings of previous research because the use of path analysis facilitated the computation of effect sizes. The proportion of the variance in the time to fall asleep explained by the use of LED light was found to be greater than the proportion of the variance in the sleep duration asleep explained by the use of LED light technology. The conclusion is that the use of LED light technology before bed may have a greater effect on increasing the students’ time to fall asleep than it does on decreasing their sleep duration. However, this conclusion is not definitive because the results of path analysis based on survey data cannot prove the existence of cause and effect relationships (Collier, Sekon, & Stark, 2010; Pearl, 2009; Ward, 2013).

Discussion and Implications

The use of LED technology before bed is known to suppress melatonin onset, resulting in sleep deprivation, altered sleep patterns, and decreased sleep efficiency (Chang et al. 2015; Lemma, et al., 2014; Lemola et al., 2015). Engagement with LED technology within one hour before bedtime (National Sleep Foundation, 2011) has been
found to be associated with decreased sleep duration, reduced sleep quality, later wake times, and impaired daytime functioning (Cain & Gradisar, 2010; Lemola et al., 2015). In this study, students reported that they used LED technology for nearly one hour before bed, which has been found to be the same duration of time needed from LED light to suppress melatonin (Wood, Rea, Plitnick, & Figueiro, 2013).

College students in this study were found to spend the most time using their smartphones and laptops before bedtime. This finding is consistent with previous literature which indicates that every day, the majority of college students use LED technology, especially before bed (Demirci et al., 2015; Lemola et al., 2015) with the heaviest usage spent first with smartphones and then laptops (National Sleep Foundation, 2011). Further research that explores the specific activities college students are engaged in while using each device and which device(s) are used simultaneously before bedtime would be beneficial. Research has shown that engagement with multiple devices during evening hours has shown to produce the greatest decrease in total hours slept, changes in school performance, difficulties with higher functioning and degradation of neurological behavior (Calamaro, Mason, & Ratcliffe, 2009).

It is proposed that individuals who use LED light technology for an extended time before bed are more likely to experience difficulties in falling asleep as well as a shorter total sleep duration (Calamaro et al., 2009; Murdock, 2013; Thomee, et al., 2007; 2010). This coincides with findings from this study in which the majority of students slept for less than seven hours during the night, which also relates to previous studies revealing that the majority of college students sleep for less than the recommended eight hours and twenty-two minutes (Lund et al., 2010; Oginska & Pokorski, 2006). This finding may
also contribute to why college students are among the most sleep deprived population in the nation (Lund, Reider, Whiting, & Prichard, 2010; Adams et al., 2016).

To date, most research has primarily explored the effects of technology device use on K-12 students. Results from this study extend the limited existing findings on the college population in the support for greater in-depth exploration about the effects of students using LED technological devices prior to bedtime. These devices have now become a necessity among this population because of their convenience and practicality. Moreover, college students should be particularly interested in these data because their independent lifestyles allow them greater freedom than K-12 students to dictate their sleep-wake schedules. Sleep is a controllable and essential factor in academic achievement that is being heavily sacrificed among a population that needs it the most (Dewald-Kaufmann et al., 2010). Knowledge about all aspects relevant to this population that likely influence sleep deprivation is significant for useful implications.

**Academic Achievement and Sleeping Behavior—Hypothesis 2**

The second hypothesis stated that students who report a long time to fall asleep will also report a short sleep duration and low scores for academic achievement.

**Conclusions**

The second hypothesis was partially supported. Three models were used to test this hypothesis. No correlation was found between time to fall asleep and sleep duration for college students. Furthermore, no support was found between increased time falling asleep, decreased sleep duration, or a decreased level of academic achievement indicated
by the MSLQ variables or the AGT variables. However, support was found between increased sleep duration and focus both during and outside of class.

Results were partially consistent with the second hypothesis because students who reported an increase in focus during and outside of classes reported longer sleep duration. The time taken to fall asleep and total sleep duration were not shown to be related.

**Discussion and Implications**

Focus was included in this study because it represents a form of academic achievement that was not measured within the AGT and MSLQ. Focus may not directly measure the students’ long-term mastery learning, motivation strategies or goals; however, focus can provide a possible measure of the students’ short-term ability to pay attention inside and outside classes in order to achieve their short-term goals and motivate themselves.

Previous research has concluded that sleep deprivation and altered sleep patterns are associated with substantial detriments to academic achievement, complex cognitive tasks, memory retention, and higher cognitive functioning (Brown et al., 2001; 2002; Perkinson-Gloor et al. 2013). More specifically, reduced concentration and attention, delayed reaction time, impaired memory functionality, and alertness during the daytime are associated with sleep deprivation at night (Alapin et al., 2000; Samkoff & Jacques, 1991; Taylor et al, 2013). Therefore, a low level of focus during the daytime, both inside and outside of classes, can be linked to reduced concentration, alertness, and attention from sleep deprivation. If so, then the significant correlations between sleep duration and focus inside and outside the classroom indicated by the path analysis may possibly be explained. Students with a short sleep duration reported low focus scores and students
with a long sleep duration reported high focus scores because (a) the students with a shorter sleep duration at night experienced reduced concentration, alertness, and attention (and hence a low level of focus) during the day; while (b), students with a longer sleep duration did not experience reduced concentration, alertness, and attention during the day and hence they reported a higher level of focus.

In this study, no correlation was found between time to fall asleep and total sleep duration, which is likely due to the unique nature of the college population. College students’ schedules are not as regimented as K-12 students who are required to rise early every day during the week and be cognitively present for an extended period of time. College students have more flexibility in their schedules and may not attend classes every day. This allows students to sleep in and reduce delayed sleep patterns, which includes sleep deprivation. Future studies should explore college students with morning and evening classes, part-time and full-time jobs, and include course load to further clarify the effects of sleep deprivation on focus during and outside of classes.

**Academic Achievement and LED Usage—Hypothesis 3**

The third hypothesis argued that students who report low usage of LED technology before bed will also report high scores for academic achievement.

**Conclusions**

The third hypothesis was partially supported. Three models were used to test this hypothesis. No statistical support was found between increased levels of academic achievement indicated by the MSLQ and the AGT variables, and decreased usage of LED light technology before bedtime. However, partial support was found between focus
during class and focus outside of classes when the use of LED light technology before bed increased.

Study results were somewhat consistent with the third hypothesis because college students who reported higher levels of focus during the day, inside and outside of their classes, also reported lower usage of LED light technology before bed.

**Discussion and Implications**

The MSLQ and AGT variables were not correlated with usage of LED technology; however, the statistically significant results of the path analysis indicated that students who reported high levels of focus during and outside of classes also reported low usage of LED light technology before bed. Conversely, students who reported low levels of focus during and outside of classes also reported high usage of LED light technology before bed.

The use of LED technology before bed is known to result in sleep deprivation, altered sleep patterns, and decreased sleep efficiency (Chang et al. 2015; Lemma, et al., 2014; Lemola et al., 2015). Previous studies have shown that engagement with LED technology at the end of the day can become a distraction, leading to increased interaction with the devices, which delayed sleep even if participants were already tired (Acharya, Acharya, & Waghrey, 2013). Sleep deprivation is known to be associated with a lack of concentration and alertness (Alapin et al., 2000; Samkoff & Jacques, 1991), which may be linked to focus. Consequently, the results of the path analysis indicated the possibility of links between LED usage, sleep duration, and focus.

**Practical Implications**
Attending college is a highly sensitive period in development when students need a substantial amount of sleep for proper neural functioning, peak cognitive arousal, elevated moods, and sustained mental concentration (Bear et al., 2007). The creation and analysis of the path models used in this study allowed for greater understanding of the relationship between LED technology usage before bedtime, sleep deprivation, and the effects on academic achievement.

In this research, the only statistically significant predictor of academic achievement pertained to a student’s level of focus both during and outside of classes. The degree of focus was related to increased or decreased usage of LED technology before bedtime which likely affected students’ amount of sleep duration. No definitively conclusions can be made that usage of LED technology before bedtime directly affects academic achievement. However, focus of attention and concentration is a necessary component of academic success; therefore, students should consider new approaches to LED technology use and duration to enhance the probability of their academic success.

Additionally, since the measurement scales pertaining to academic achievement in this study were negatively related to LED technology use and sleep duration, researchers should continue to examine college students’ academic achievement over a longer duration of time. Further investigation about the level of influence that LED technology usage during bedtime has on focus and performance may encourage better technology habits. To change this behavior, it would be highly beneficial for universities and educators to present students with statistical findings about how the intensity and duration of specific LED technology devices used prior to bedtime affects academics based on credit hours, sleep duration, majors, extracurricular activities, and job commitments. At
the very least, this study provides support for the contention that one’s ability to focus impacts academic achievement.

Until more research can be conducted, educators can express the benefits of using self-regulation to cease LED technology usage earlier in the evening and during classes. Exemplifying the benefits of technology discipline may enhance greater acquisition of sleep, and comprehension of material content during and outside of classes.

Although technology has become a beneficial resource supporting learning, stressing the importance of how it can negatively affect focus and progress would likely impact student attitudes.

The results from this study add to the findings from previous studies that have highlighted the effects of LED technology usage before bedtime, which may prolong the time to sleep, shorten the level of sleep duration, and reduce the level of focus during the day. Policies should be considered and encouraged throughout universities by educators and administrators in order to: (a) make students more aware of the potential influences of LED light technology usage before bedtime; and (b) define objective criteria to identify exactly how long LED light technology should be used before bedtime in order to avoid those detrimental effects.

**Limitations**

Numerous limitations to this study were discussed at the end of Chapter Three; however, additional limitations will be presented here. The sleep survey questions and measurement scales in this study could not possibly consider all potential factors affecting students’ pre-sleep activities, sleep duration, and academic achievement. For
instance, the consumption of coffee/tea, stimulant drinks, alcohol intake, prescription
drugs, nicotine intake, and purely academic performance (e.g., test grades) are all
important factors that likely affect or are affected by sleep and were not explored in this
study (Lund, Reider, Whiting, & Prichard, 2010; Trockel, Barnes, & Egget, 2000).
Additionally, the exact duration of time students spent using each LED device and the
distance from the eyes needs to be considered in future studies since this can influence
melatonin onset during bedtime (Asaoka, Fukuda, Tsutsui, & Yamazaki, 2007; Oh, Yoo,
Park, & Do, 2015).

In regard to the statistical analyses, the adage that “absence of evidence is not
evidence of absence” (Altman & Bland, 1995, p. 311; Alderson, 2004, p. 476) applies. $P$-
values that do not indicate statistical significance, do not necessarily imply that there is
an absence of evidence regarding the relationships between variables $P$-values not being
a “gold standard” of statistical validity or that they are not as reliable as many researchers
assume (Nuzzo, 2014). Inferential statistical analyses are fickle and $p$-values often
generate irreproducible results (Halsey, Curran-Everett, Vowler, & Drummond, 2015).
There are many reasons why $p$-values based on one set of data may reflect no significant
relationships between variables, when, in fact, statistically significant relationships may
be found if another set of data is analyzed. A major reason for this is that the data
violated the assumptions of the analysis. For example, path analysis assumes that the
variables are accurately measured and are not distorted by any form of bias. The students’
responses to the Sleep Study Survey, the MSLQ and AGT, however, may have been
distorted by up to 48 forms of response bias that are commonly associated with the
collection an analysis of self-reported data (Choi & Pak, 2005). These sources of bias
could include faking the answers to the questions through socially desirable responding (Mortell Van De, 2008) might include an example of faking or the failure of the respondents to accurately recall past experiences, such as sleep duration (Lauderdale et al., 2008). It is possible, therefore that response bias generated inaccurate data, resulting in the failure to find statistically significant correlations between time to fall asleep, sleep duration, and academic achievement using the data collected with the Sleep Study Survey, MSLQ, and AGT.

Finally, when respondents self-report information about their perceptions regarding LED usage before bedtime, sleep, and academic achievement, they often only describe the short-term perceptions they have at that particular moment in time, and not their perceptions that may change over the long term (Choi & Pak, 2005). The MSLQ and AGT measure perceptions that may change over the long term. The MSLQ measures mastery learning including the intrinsic drive for students to remain persistent over the long-term. The responses to the MSLQ emphasize the learning strategies and step-process learning levels that students must achieve before moving forward (Pintrich et al., 2013). The AGT measures a significant need for achievement, ultimately encouraging complex cognitive thinking resulting in the potential of adopting either a positive or negative mindset (Elliott & Peckrum, 2011). It has been hypothesized that sleep deprivation associated with the use LED light technology may be detrimental to these higher levels of executive functioning because they are associated with long term neural development, which takes place during sleep (Colrain & Baker, 2011; Gaultney, 2010; Tarokh & Carksadon, 2010).
Recommendations for Future Research

The main limitations of the findings from this survey, which can only be overcome by future research include: (a) the findings are not necessarily generalizable to the entire population of undergraduate students in the USA because they were derived from a convenience sample of students who volunteered to participate rather than a representative random sample drawn from a group of students who represented an undergraduate population; (b) because findings were derived from convenience samples and therefore subject to sampling bias, many of the responses to the instruments administered in this survey were significantly different from the responses to the same instruments measured by previous researchers; and (c) the path analysis to address the research questions and test the associated hypotheses could simply describe the strengths of the partial correlations between sleep duration, time to sleep, use of LED technology, and academic achievement.

The path analysis could not explain the causal relationships between the variables: sleep duration, time to sleep, use of LED technology, and academic achievement. Consequently, the purpose of future research must be directed toward finding results that: (a) are more generalizable to the entire population of undergraduate students in the USA; and (b) explain the causal relationships between sleep duration, time to sleep, use of LED technology, and the academic success of students. To analyze causal relationships, an experimental research design is required in which one or more independent causal factors are prospectively manipulated in order to determine the subsequent effects on one or more dependent variables (Collier, Sekon, & Stark, 2010; Pearl, 2009; Ward, 2013).
To examine causal relationships between sleep duration, time to sleep, use of LED technology, and academic outcomes, it will be necessary for future researchers to apply experimental designs, in which predefined hypotheses concerning the relationships between causes and effects are tested prospectively using data collected from representative samples of individuals drawn from a defined population.

For over a decade, the gold standard for medical research has been the randomized controlled trial (RCT) design (Machin & Cambell, 2005; Satake, 2015). For better understanding, the RCT design and its associated methods of inferential statistical analysis are universally implemented by medical researchers. They will examine the extent to which prescribed clinical treatments and therapies have statistically and clinically significant effects on the health outcomes of two or more randomly assigned groups of patients suffering from a specific disease. One group of patients is randomly assigned (e.g., by tossing a coin) to a control group who are not exposed to a prescribed treatment or therapy, and the remaining patients are randomly assigned to one or more experimental groups who are exposed to one or more prescribed treatments or therapies. In the future, an experimental RCT research design is recommended in which the treatment prescribed by the researcher is the use of LED technology.

The RCT design could be applied to this study by selecting one experimental group of undergraduate students enrolled at multiple universities and randomly assigned to use LED technology for a given length of time (e.g., three weeks). One control group of undergraduate students enrolled at multiple universities should be randomly assigned not to use LED technology for the same time period. The measured outcomes will be the time to fall asleep, the total sleep duration, and the academic performance of the students.
In order to eliminate the various sources of bias associated with the collection of self-reported data (Choi & Pak, 2005; Mortell Van De, 2008) the time of use of LED technology, the time to go to sleep, and the total sleep duration in the future recommended research should not be measured using self-report instruments. These variables could be measured objectively using electronic monitoring devices, similar to those used by Lauderdale et al. (2008) to estimate accurate measures of sleep duration. Furthermore, self-reported measures of academic achievement using the MSLQ and AGT instruments should not be administered in future research because the responses to these instruments may be biased, and compromise the results. In future research, objective measures of student performance provided by educators (e.g., the GPA scores of each student) are recommended as the outcome variables to determine the effects of sleep duration, time to sleep, use of LED technology on academic performance (i.e., receiving external rewards or favorable judgments from others) rather than self-reported academic achievement.

**Conclusion**

This study has generated a lot of answers but not all the answers, and therefore better questions are being asked. The overall question of “How does pre-sleep usage of LED screen technology affect sleeping behavior and academic achievement?” could only be answered tentatively using descriptive and inferential statistical analyses of survey data. The statistically significant results of path analysis using PLS provided a descriptive understanding of how (a) the time of use of LED light technology before bed had a significantly greater effect on increasing the students’ time to fall asleep than it did
on their sleep duration; (b) the students with a longer sleep duration reported higher scores for focus during and outside classes when their sleep duration was shorter; and (c), students who reported high levels of focus during and outside classes also reported low usage of LED light technology before bed. The use of convenience samples, the administration of self-report instruments, and the use of path analysis did not provide any objective information to prove the existence of causal relationships, nor were the responses to the ESS, MSLQ, and AGP instruments consistently in agreement with the responses reported by the developers of the instruments. In order to overcome these limitations in future, an experimental RCT design, widely used in medical research, is recommended to address research questions concerning causal relationships, using objectively measured variables; such as “What are the direct effects of the time of use of LED technology before bed on the time to go to sleep and the total sleep duration of undergraduate students”; and “What are the direct effects of the time of use of LED technology before bed, the time to go to sleep, and the total sleep duration on the academic outcomes of undergraduate students?”. 
References


http://www.tc3.edu/instruct/sbrown/stat/correl.htm


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Murdock, K.K. (2013). Texting while stressed: Implications for students' burnout, sleep,


Appendix A: Sleep Study Survey

Sleep Study

Adult Information Sheet for Research
University of Cincinnati Division: Educational Studies
Principal Investigator: Jessica Kestler, M.S.
Title of Study: Journal of Academic and Sleep Behaviors

Introduction: You are being asked to take part in a research study. The weekly survey should take 15-30 minutes to complete. To receive full credit for taking part in this study, participants must complete each survey, for all three weeks.

Purpose and Criteria: The purpose of this research study is to assess students’ evening activities and sleeping behavior that may or may not influence academic achievement. You may participate in this study if you are a college student (and at least 18 years of age). If you volunteer to participate in this study you will be asked to log questions pertaining to evening activities, sleeping behavior, and academic behavior on a weekly basis. This online journal link will be emailed to participants' every Monday for weekly logging.

Risks/Benefits: This study includes only minimal risks. You are unlikely to experience any discomfort during this study; however, if you do become uncomfortable for any reason you may withdraw from the study at any time without penalty. There are no financial costs or rewards to you for completion of this study. Confidentiality Information about you will be kept private by separating your name from your responses. Instructors will not be provided any information that can link any particular responses to any particular participant. Your information will be kept on a password-protected computer in a locked office at UC for 3 years. After that the principal investigator will delete it. Any questions or concerns, please contact the Principal Investigator, Jessica Kestler, at KESTLEJL@UCMAIL.UC.EDU.

Consent: By partaking in this research study, you are confirming that you have read the above information and indicate your consent to participate in this research study. You may print this information sheet for your reference.

Please provide your name below to confirm your consent. Your name will be separated from the rest of your survey, to maintain confidentiality.
Please confirm the class for which you would like to receive research credit for (i.e. EDST 1002, EDST 2001, etc.):

The first portion of this survey will contain basic demographic questions. Note that after the first week, several demographic questions will not be repeated. Please answer each to the best of your abilities and thank you in advance for your participation!

Q1 Please state your age (month/year).

Q2 Gender
- Male
- Female
- Other

Q3 In what school/college are you currently enrolled at the University of Cincinnati?
- Allied Health Sciences
- Arts & Sciences
- Business
- College-Conservatory of Music
- Design, Architecture, Art, & Planning
- Education, Criminal Justice, & Human Services
- Engineering & Applied Sciences
- The Graduate School
- Law
- Medicine
- Nursing
- Pharmacy
- UC Blue Ash College
- UC Clermont College

Q4 Please self-designate your current or future academic major.

__________________________________________________

Q5 Ethnicity
- Caucasian/White
- Hispanic/Latino
- Native American
- Black/African-American
- Asian
- Pacific-Islander
- Other _________________
Q6 How many roommates do you live with?
○ 0
○ 1
○ 2
○ 3
○ 4
○ 5
○ 6 or more

Q7 Is your sleep space dark enough?
○ Not at all dark enough
○ Somewhat dark enough
○ Dark enough
○ Very dark enough

Q8 Is your sleep space quiet enough?
○ Not at all quiet enough
○ Somewhat quiet enough
○ Quiet enough
○ Very quiet enough

Q9 How many credit hours are you enrolled in this Spring 2017 semester?

Q10 What is your current cumulative GPA?
Q11 Please indicate your TOTAL MINUTES spent on each item during the previous week. If you did not partake in that activity, please put zero.

Remember,
1 hour = 60 minutes
2 hours = 120 minutes
3 hours= 180 minutes
4 hours= 240 minutes

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<th>At Job</th>
<th>Social Activities</th>
<th>Slept</th>
<th>Leisure</th>
<th>Physical Activity</th>
<th>Outside Class Work</th>
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The first portion of this survey involves journal entry and item response questions about your sleep patterns and academic behavior. I ask that you answer all questions and please answer each item to the best of your ability. Thank you very much in advance for your diligence.

Q12 How many HOURS of sleep PER NIGHT do you think is recommended for someone in your age group?

_________________________ Hours of sleep per night
Q13 Do you sleep the SAME number of HOURS on the WEEKENDS vs. WEEKDAYS?
- Yes
- No

Q14 If you answered NO to the previous question, how do the HOURS DIFFER?
- 3 or more on weekends
- 2 or more on weekends
- 1 or more on weekends
- 1 or less on weekends
- 2 or less on weekends
- 3 or less on weekends

Q15 On average, across the last 7 days, HOW LONG did it take you to FALL ASLEEP on any given day?

_________________

Q16 Starting on MONDAY the previous week, what was the QUALITY of your sleep for each evening.

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<tr>
<th></th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very Good</th>
<th>Excellent</th>
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Q17 During the previous week, was your sleep interrupted at any point in time?
☐ Yes
☐ No

Q18 If you answered YES to the previous question, CHECK ALL that interrupted your sleep each night?

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<th>Date</th>
<th>Text Messaging</th>
<th>Social Media Notification</th>
<th>Phone Call</th>
<th>Email</th>
<th>App Notification</th>
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Q19 During the previous week, HOW MANY TIMES was your sleep interrupted? If your sleep was not interrupted for that day, please put zero.

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_____ Wednesday, February 15th, 2017
_____ Thursday, February 16th, 2017
_____ Friday, February 17th, 2017
_____ Saturday, February 18th, 2017
_____ Sunday, February 19th, 2017
Q20 When you get into bed at night without technology or reading material and everything is physically put away, HOW MANY MINUTES does it take you to FALL ASLEEP?

Q21 During the previous week, HOW MANY DAYS do you lie in bed and have trouble falling asleep at night?

_____ Total Days Per Week (1)

Q22 If you NAPPED during any days of the previous week, LIST THE TOTAL MINUTES napped for that day. If you did not nap during that day, please put zero.

_____ Monday, February 13th, 2017
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_____ Wednesday, February 15th, 2017
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_____ Friday, February 17th, 2017
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_____ Sunday, February 19th, 2017

Q23 During the previous week, did you use one or more of the following items listed below WITHIN 120 MINUTES (2 HOURS) of falling asleep? (cell phone, iPad/tablet, laptop, desktop, or television)

○ Yes
○ No

Q24 Please RANK order from MOST to LEAST which devices you use 120 minutes (2 hours) prior to falling asleep in the previous week.

_____ Cell Phone
_____ iPad/Tablet
_____ Laptop
_____ Desktop Computer
_____ Television
Q25 If you answered YES, to the previous questions. On average, HOW MANY MINUTES did you use the following devices in the previous week. If you did not use that device, please put zero.

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<th>iPad/Tablet</th>
<th>Laptop</th>
<th>Desktop Computer</th>
<th>Television</th>
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Q26 In the previous week, SELECT ALL CELL PHONE brands you used.
- Apple
- Samsung
- LG
- HTC
- Motorola
- Google
- Other

Q27 In the previous week, SELECT ALL TABLET brands you used.
- Apple
- Samsung
- Microsoft
- LG
- Amazon
- Visual Land
- Other
Q28 In the previous week, SELECT ALL LAPTOP and COMPUTER brands you used.
- Apple
- DELL
- HP
- Microsoft
- Lenovo
- Acer
- Samsung
- Intel
- Asus
- Other

Q29 In the previous week, SELECT ALL TELEVISION brands you used.
- Samsung
- LG
- Sony
- Sharp
- Vizio
- Toshiba
- Insignia
- Other

Q30 During the previous week, HOW MANY MINUTES did you allocate each day to solely focusing on studying or homework for your classes? It is OK to move the slider between number values (e.g., 45 minutes).
- _____ Monday, February 13th, 2017
- _____ Tuesday, February 14th, 2017
- _____ Wednesday, February 15th, 2017
- _____ Thursday, February 16th, 2017
- _____ Friday, February 17th, 2017
- _____ Saturday, February 18th, 2017
- _____ Sunday, February 19th, 2017

Q31 How many major assignments did you have due this past week?

Q32 How many major exams, quizzes, tests did you have this past week?

Q33 Did you meet up or converse with classmates outside of class this past week FOR STUDYING PURPOSES ONLY?
- Yes
- No
Q34 On the following scale, how involved were you DURING CLASSES this past week? If weekend/online classes do not apply to you, please leave those days blank.

<table>
<thead>
<tr>
<th>Date</th>
<th>Extremely Uninvolved 1</th>
<th>Very Uninvolved 2</th>
<th>Somewhat Uninvolved 3</th>
<th>Somewhat Involved 4</th>
<th>Very Involved 5</th>
<th>Extremely Involved 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday, February 13th, 2017</td>
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<td>Sunday, February 19th, 2017</td>
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</tbody>
</table>
Q35 On the following scale, how involved did you feel in academic course work OUTSIDE of class this past week?

<table>
<thead>
<tr>
<th>Date</th>
<th>Extremely Uninvolved</th>
<th>Very Uninvolved</th>
<th>Somewhat Uninvolved</th>
<th>Somewhat Involved</th>
<th>Very Involved</th>
<th>Extremely Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday, February 13th,</td>
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<td>Wednesday, February 15th</td>
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<td>Friday, February 17th,</td>
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<td>Sunday, February 19th,</td>
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</tbody>
</table>

Q36 What is YOUR ideal LENGTH OF SLEEP per night to function well?

___________ Ideal HOURS of sleep per night

Q37 If you have ANY OTHER COMMENTS to add from the previous week, you can elaborate in the space provided below.

The next few pages will consist of measurement scale items. I RECOGNIZE THAT THERE ARE SURVEY ITEMS THAT WILL APPEAR VERY SIMILAR TO ONE ANOTHER. Please know that this is done on purpose to validate the consistency of your responses. Please respond to the best of your ability and to respond to all items regardless of their similarity to other items. Thank you again for your participation.
Q38 Please indicate how well each statement describes the chance that you would doze off or fall asleep during different routine daytime situations given your recent lifestyle. Even if you have not done some of the activities, think about how they would presently affect you. The items are rated from 0 to 3: with 0 meaning you would never doze or fall asleep in a given situation; and 3 meaning that there is a very high chance that you would doze or fall asleep in that situation.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Would never doze off or sleep (0)</th>
<th>Slight chance of dozing off or sleeping (1)</th>
<th>Moderate chance of dozing off or sleeping (2)</th>
<th>High chance of dozing off or sleeping (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting and reading</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Watching television or a video</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Sitting in a classroom at school during the morning</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Sitting or riding in a car or bus for about half an hour</td>
<td>○</td>
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<tr>
<td>Lying down to rest or nap in the afternoon</td>
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<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Sitting and talking to someone</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Sitting quietly by yourself after lunch</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Sitting and eating a meal</td>
<td>○</td>
<td>○</td>
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</tr>
</tbody>
</table>
Q29 While thinking about this class, please respond to the following questions about your learning behaviors. Please respond to the best of your ability. Use the scale below to respond to each item.
Selecting 6 indicates that the statement is VERY true of you.
Selecting 1 indicates that the statement is EXTREMELY untrue of you.
<table>
<thead>
<tr>
<th></th>
<th>Extremely untrue of me</th>
<th>Very untrue of me</th>
<th>Somewhat untrue of me</th>
<th>Somewhat true of me</th>
<th>Very true of me</th>
<th>Extremely true of me</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In a class like this, I prefer course material that really challenges me so I can learn new things.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>I believe I will receive an excellent grade in this class.</td>
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<tr>
<td>3</td>
<td>I’m certain I can understand the most difficult material presented in the readings for this course.</td>
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<tr>
<td>4</td>
<td>Getting a good grade in this class is the most satisfying thing for me right now.</td>
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<tr>
<td>5</td>
<td>The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.</td>
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</tbody>
</table>
6. I’m confident I can learn the basic concepts taught in this course.

7. If I can, I want to get better grades in this class than most of the other students.

8. I’m confident I can understand the most complex material presented by the instructor in this course.

9. In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.

10. I’m confident I can do an excellent job on the assignments and tests in this course.

11. I expect to do well in this class.
12. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.

13. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don’t guarantee a good grade.

14. I’m certain I can master the skills being taught in this class.

15. I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.
<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.</td>
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<tr>
<td>17. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.</td>
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<td>18. I work hard to do well in this class even if I don’t like what we are doing.</td>
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<tr>
<td>19. When course work is difficult, I either give up or only study the easy parts.</td>
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<tr>
<td>20. Even when course materials are dull and uninteresting, I manage to keep working until I finish.</td>
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</table>

Q30 Please indicate how well each statement describes you in regards to your goals for your college courses. If a statement is very true of you, select 6. If a statement is not at all true of you, select 1. If a statement is more or less true of you, select the number between
2 and 5 that best describes you. There are no right or wrong responses, so please be open and honest.
<table>
<thead>
<tr>
<th></th>
<th>Not at all true of me</th>
<th>Very untrue of me</th>
<th>Somewhat untrue of me</th>
<th>Somewhat true of me</th>
<th>Very true of me</th>
<th>Extremely true of me</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To get a lot of questions right on the exams in class.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>2. To avoid incorrect answers on the exams in class.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
<td>☐</td>
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<tr>
<td>3. To perform better on the exams in class than I have done in the past on these types of exams.</td>
<td>☐</td>
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<tr>
<td>4. To avoid doing worse on the exams in class than I normally do on these types of exams.</td>
<td>☐</td>
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<tr>
<td>5. To outperform other students on the exams in class.</td>
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<tr>
<td>6. To avoid doing worse than other students on the exams in class.</td>
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<tr>
<td>7. To know the right answers to the questions on the exams in class.</td>
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<tr>
<td>8. To avoid getting a lot of questions wrong on the exams in class.</td>
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<tr>
<td>9. To do well on the exams in class relative to how well I have done in the past on such exams.</td>
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<tr>
<td>10. To avoid performing poorly on the exams in class compared to my typical level of performance.</td>
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<td>11. To do well compared to others in class on the exams.</td>
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<td>12. To avoid doing poorly in comparison to others on the exams in class.</td>
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<td>13. To answer a lot of questions correctly on the exams in class.</td>
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<td></td>
<td>14. To avoid missing a lot of questions on the exams in class.</td>
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<td></td>
<td>15. To do better on the exams in class than I typically do in this type of situation.</td>
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<td></td>
<td>16. To avoid doing worse on the exams in class than I have done on prior exams of this type.</td>
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<tr>
<td></td>
<td>17. To do better than my classmates on the exams in class.</td>
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<tr>
<td></td>
<td>18. To avoid performing poorly relative to my fellow students on the exams in class.</td>
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