NATURE AND PUBLIC SCHOOL STUDENTS: EXAMINING THE LINK BETWEEN ACADEMIC FUNCTIONING AND SCHOOL NATURE

by

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ABSTRACT

JENNIFER TAYLOR SCOTT. Nature and public school students: Examining the link between academic functioning and school nature. (Under the direction of DR. RYAN P. KILMER).

Although research has demonstrated that nature exposure (i.e., environments with natural features such as vegetation or greenspace) has the potential to improve individuals' psychological and physical well-being, little research has investigated potential student benefits related to nature exposure near schools (i.e., school nature). Mechanisms thought to explain benefits of nature exposure include cognitive and physiological responses that improve in relation to stress reduction; these responses may also yield additional benefits to students' academic functioning. This study investigated the extent to which kindergarten through 8th grade students in traditional, public schools in Charlotte-Mecklenburg, North Carolina exhibited better academic functioning (i.e., higher test scores, fewer behavioral incidents) in relation to school nature (i.e., nearby tree canopy and permeable surface). Nature indicators were assessed using Geographic Information Systems, and data were analyzed using multilevel modeling to control for interdependence among students attending the same school. A primary study aim assessed the degree to which student academic functioning was sensitive to prediction by nature indicators at a tenth-, quarter-, or half-mile from the school. Results were largely inconsistent with expectations because few associations suggested that students exhibited better academic functioning in schools with more nearby nature. One significant association indicated that students in schools with more permeable surface within a half-mile performed slightly better on academic testing; therefore, half-mile nature indicators were used in subsequent analyses. The study also aimed to estimate an optimal dose of nature exposure for student functioning. While most associations were not significant, findings indicated that the risk of a behavioral incident was greatest in schools with Average to High Canopy compared to schools with Low or Very High Canopy; these results were counter to expectations. Lastly, the study investigated whether academic disparities related to group and school characteristics (i.e., such as being male, adolescent, Black, immigrant, in a low-income school, or having disability status) were heightened or minimized in the context of greater nature exposure. Although results regarding most potential moderators were not significant, analyses indicated that the heightened risk of a behavioral incident in relation to greater tree canopy was greatest for Black students and least for students with limited English proficiency (LEP). Findings also indicated that LEP students performed worse academically in schools with greater tree canopy, whereas non-LEP students performed similarly regardless of nearby nature. Possible explanations for these largely unexpected results considered the potential for tree canopy within a half-mile of schools to be crowded or unmanaged, which may evoke a fear response among students. According to prior research, a fear response may be particularly salient among students of color. Furthermore, these results may be attributed, at least in part, to some key study limitations. In particular, strong conclusions cannot be drawn because of the study’s correlational nature and the omission of several variables that may explain study results, including neighborhood disadvantage (e.g., poverty, crime), school discipline practices, tree canopy quality, and a neighborhood’s proportion of immigrant residents. Implications of this work and future directions for research and intervention are considered.

DEDICATION

For all the people who helped me get to where I am today, especially my family. I would not have excelled academically to make it into college and graduate school if it were not for the countless hours my mother spent studying with me every night and reminding me that I had to work hard to achieve my dreams. Similarly, my father's words echo in my mind, "you can be anything you want to be as long as you put your mind to it". And where would I be, literally, if he hadn't made himself available to pick me up roadside for car problems on numerous occasions! Relatively more recently, my husband Josh's unending encouragement, empathy, and commitment (as well as acting as financier and constant caretaker) has undoubtedly been a stronghold for me during my graduate training.

My grandparents have all played important roles in my life, and if it were not for my nissy and poppy's passion for humanitarian service, I am unsure if I would have been inspired to pursue such a rewarding career path – seeking to be the change I want to see in the world. My heart swells with pride when I consider how they have exemplified love and compassion, and I would be honored to be half as successful as they have been in making a difference in the lives of those who suffer. Importantly and relatedly is the Faith that I share with my family, which has unequivocally granted me the strength, hope, and courage to become the person I am today.

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CHAPTER 1: INTRODUCTION

A growing body of research suggests that people thrive in a number of ways when exposed to natural elements (e.g., trees, green spaces) due to improved physiological and psychological functioning; however, the research is less well-developed regarding nature's potential benefits for children in academic settings. The present study sought to examine the extent to which public school students exhibited better academic functioning (i.e., test performance and behavioral incidents) when their schools were near more natural elements (e.g., trees, green spaces; i.e., school nature or nearby nature; see section 1.4 for a thorough conceptualization of nearby nature), relative to students exposed to lower levels of nature in the school context. Although prior research indicates that children tend to exhibit greater socio-emotional strengths and fewer behavioral challenges when exposed to natural elements (e.g., Scott, Kilmer, Wang, Cook, & Haber, 2015), little is known about students' academic functioning in relation to more or less nature near schools.

Existing research exploring the relationship between academic performance and nature exposure has yielded mixed results that are difficult to interpret due to methodological and population differences (e.g., Benfield, Rainbolt, Bell, & Donovan & Prestemon, 2012; Han, 2009; Matsuoka, 2010). Furthermore, minimal research has explored the possibility that some individuals may benefit more from nature exposure than others (Hartig, Mitchell, de Vries, & Frumkin, 2014) or sought to identify the optimal level of nature exposure that can maximize benefits (Shanahan, Fuller, Bush, Lin, & Gaston, 2015). This study sought to build on the existing research by (1) examining the relationship between nature exposure near school grounds and children's academic functioning; (2) estimating the optimal level of nature exposure for children's academic functioning; and (3) exploring nature exposure as a potential moderator of relationships between nature exposure and functioning, analyses that can shed light on for whom nature exposure may be most beneficial.

The following sections describe (a) major theories that help clarify potential mechanisms underlying the benefit of nature exposure, (b) previous research investigating academic and behavioral benefits of nature in the school context, (c) a theoretical framework for the current investigation, (d) limitations of the extant literature and how the present study sought to build upon prior research by examining nearby nature, (e) rationale for identifying the optimal level or "dose" of nature exposure, (f) potential benefits of understanding the degree to which nature exposure may buffer the effects of adversity among certain students, (g) the study context, and (h) its research questions and hypotheses.

1.1 Theoretical Framework: How Nature Exposure may Contribute to Academic Functioning

Green space and nature exposure are contextual factors that contribute to a broader ecology that directly and indirectly influences human behavior and well-being. As such, a critical meta-theory for conceptualizing the benefits of nature is ecological systems theory (Bronfenbrenner, 1979; also known as bioecological theory; Bronfenbrenner & Morris, 2006), which emphasizes the interaction and mutual influence of factors within and across the “nested” levels of a child’s context (e.g., child characteristics, social systems, schools, neighborhoods). Applied to the current study’s objectives, diverse factors at the student-, school-, and neighborhood-levels interact and influence student development and functioning. Another critical lens is offered by environmental psychology, which focuses more specifically on bidirectional influences between individuals and their physical surroundings (Kloos et al., 2012). These meta-theories or approaches provide a substantive foundation for understanding the influences of contexts on human development, behavior, and adaptation; however, there are two specific theories that have been used to explain explicitly how nature exposure benefits human health and behavior.

Attention restoration theory and psychoevolutionary theory are most frequently cited as describing the processes that potentially underlie the relationship between nature exposure and various dimensions of well-being. Attention restoration theory (Kaplan & Kaplan, 1989) emphasizes the relief from directed attention, which requires inhibition from distracting stimuli, that occurs in natural settings due to “fascination” (p. 184), or involuntary interest in stimuli that does not require directed attention. Instead, “involuntary attention” (i.e., requires no effort; p. 179) is evoked through the aesthetic and rhythmic appeal of natural stimuli (e.g., motion of leaves in a breeze). According to Kaplan and Kaplan (1989), this restorative process is characterized by reflection, a sense of “escape” (p. 183), and “clearing of the head” (p. 196), which allows individuals to recover from “mental fatigue” (p. 178) caused by more purposeful and intentional cognitive efforts typical of humans’ goal-oriented behaviors.

Alternatively, psychoevolutionary theory emphasizes a conditioned response in which natural stimuli unconsciously trigger positive emotional and physiological responses because of their association with survival of the human species (e.g., water, shelter; Ulrich, 1983). In this view, because human neurological and sensory systems developed in natural environments, individuals may associate natural stimuli with safety and predictability (Ulrich et al., 1991). Therefore, according to this theory, it is expected that individuals experience relatively lower stress in natural environments compared to urban or built environments, and lower stress contributes to more efficient cognitive processes (Ulrich et al., 1991).

Both attention restoration and psychoevolutionary theories suggest that critical mechanisms underlying the relationship between nature and human benefits are physiological stress responses and cognitive functioning; however, these theories hypothesize a different temporal order (and direction) for these processes (Kaplan, 1995). That is, while attention restoration theory emphasizes cognitive overload and mental fatigue as causes of physiological stress responses, psychoevolutionary theory asserts that physiological stress responses diminish cognitive capacities such as attention (Kaplan, 1995). The co-occurrence of attention fatigue and physiological indicators of stress makes it difficult to ascertain the actual sequence of processes described in either theory (Kaplan, 1995). Although specific, causal mechanisms remain unclear, research supports the links between nature exposure, cognitive functioning (e.g., attention; Taylor & Kuo, 2009), and physiological indicators of stress (e.g., reduced blood pressure, Kelz, Evans, & Röderer, 2013; lower cortisol levels, Ward Thompson et al., 2012; and brain wave patterns, Roe, Aspinall, Marvos, & Coyne, 2013).

It bears mention that similar phenomena have been observed in studies of mindfulness meditation, an approach that emphasizes nonjudgmental awareness of present experiences (Kabat-Zinn, 2003). Mindfulness practice might also be useful in conceptualizing the benefits of nature exposure, as there is a parallel between "fascination" with a continuous flow of natural stimuli (Kaplan & Kaplan, 1989) and the sensory focus on experiences in present-time that is central to mindfulness approaches (Holzel, Lazar, Schuman-Oliver, Vago, & Ott, 2011). Further, prior research has established a link between aspects of mindfulness (i.e., attention, awareness, and acceptance) and nature exposure (Howell, Dopko, Passmore, & Buro, 2011). Such findings may hold relevance for practical applications (e.g., intervention, design modifications) drawing on the potential benefits of nature exposure.

1.2 Research on Academic Benefits of Nature Exposure

A wide-ranging research base on the potential impact of nature has emerged in recent decades, most of which has focused on health-related benefits for adults. That said, the vast majority of investigations involving children suggests that nature exposure can support healthy development (Gill, 2014; White, 2004), such as psychological well-being (e.g., Roe & Aspinall, 2011), socio-emotional and behavioral competencies (e.g., Scott et al., 2015), and cognitive functioning (e.g., Taylor & Kuo, 2009). Scant research has examined relationships between nature exposure and child functioning in the context of traditional public schools; therefore, the present review draws upon the broader extant literature base, beginning with what is known generally about the potential influence of schoolyard greenness, then describing relationships between nature exposure and academic functioning, including behavior problems and academic achievement. The brief overviews that follow for each of these domains of academic functioning describe associations generally (i.e., regardless of setting), then distill what has been learned from non-traditional, school-based approaches or programs (such as school gardens, involving students growing plants near traditional schools, or forest schools, in which learning is outdoors in forests as opposed to a traditional classroom setting), and conclude with studies conducted in traditional school contexts.

1.2.A The Potential Influence of Schoolyard Greenness

The lack of research exploring the potential benefits of nature exposure in the school context is noteworthy for a number of reasons. On average, schoolyards have become largely barren landscapes that lack shade, shelter, and vegetation other than turf grass (e.g., White, 2004). In fact, data from schools in three major U.S. cities indicate that schoolyards tend to be dominated by grass and impervious surface (i.e., built structures that water cannot pass through), and comprised of little tree canopy (i.e., the percentage of land area covered by tree foliage; Schulman & Peters, 2008). In light of the amount of time children spend in schools, it is expected that environmental conditions in the school context can play a substantive role in children's development (e.g., Kelz et al., 2013; Monsur, 2015). Therefore, environmental interventions in the school context could have significant impact on students.

Moreover, the potential for nature near schools to yield benefits for students' development and academic functioning is bolstered by research that has demonstrated that students perceive schoolyards as more restorative when there is abundant vegetation (Akpinar, 2016; Bagot, Allen, & Toukhsati, 2015), and attention and stress levels improve when students have window views of green spaces in comparison to having no window or windows with barren (i.e., no vegetation) views (Chen, 2014; Li & Sullivan, 2016). Additional research is needed to understand the degree to which nature near schools can enhance students' academic functioning.

1.2.B Nature Exposure and Behavior Problems

Limited research has investigated children's behavior in relation to nature exposure, and existing studies have largely focused on symptoms related to Attention Deficit/Hyperactivity Disorder (ADHD), including behavioral ratings of impulsivity, hyperactivity, and/or inattention (e.g., Wells, 2000), and cognitive testing of attention and impulsivity (e.g., Faber Taylor & Kuo, 2009). This research suggests that nature exposure has the potential to improve impulsivity and ADHD-related behaviors substantially (e.g., Faber Taylor & Kuo, 2009; Wells, 2000). Moreover, some investigations have focused on specific aspects of children's behavior, such as impulsivity and negative emotionality, that are strongly associated with problem behaviors (Eisenberg et al., 2005); each of these challenging attributes have been found to be less prevalent among children who are exposed to high levels of nature (e.g., Roe & Aspinall, 2011; Wells & Evans, 2003).

The existing literature is further limited by the fact that most of the behavioral research has been done outside the school context. For example, a small set of studies has examined the association between nature nearby children's homes and has demonstrated that children, especially those of low socioeconomic status (SES), living near green spaces tend to be rated as exhibiting higher levels of attention and prosocial behaviors, and as less likely to exhibit conduct problems, impulsivity, and hyperactivity (Balseviciene et al., 2014; Markevych et al., 2014; Wells, 2000). However, these studies are largely correlational, and selection issues (e.g., parents who choose to live in greener neighborhoods may also have children who are more highly functioning) limit the degree to which it is possible to draw causal conclusions about the benefits of residential greenspace.

Additional research has explored behavior in non-traditional schools (e.g., forest schools) or school programs (e.g., school gardens). These efforts suggest that interacting with nature has the potential to improve students' happiness, self-esteem, self-control, anger, energy and stress levels, interpersonal skills, and sense of belonging with the school, (Gill, 2014; Lovell, O'Brien, & Owen, 2010; Mirrahimi, Tawil, Abdullah, Surat, & Usman, 2011; Roe & Aspinall, 2011). However, these findings are not conclusive regarding potential benefits of nearby nature because those interventions explicitly engage students in natural settings. Put another way, there are clear challenges in trying to generalize or apply such findings because these efforts reflect meaningful differences in scope and intensity from what might be possible in the context of a more typical school setting.

The settings of interest in the present study were traditional, public schools where children were passively exposed to natural elements in or near the school context. Few studies were found for this review that examined academic functioning, such as test performance or school discipline records (e.g., suspensions), related to schools' nearby nature. As one example, a quasi-experimental study found that students in Taiwanese classrooms containing several small trees were less often punished for misbehavior and had better attendance compared to students in classrooms with no trees (Han, 2009). Similarly, a study among southern Michigan high schools found that schools with more natural cafeteria views (i.e., the degree of nature visible from the cafeteria windows) and landscapes (i.e., presence of trees and shrubs) had students who evidenced lower levels of “criminal activity” (e.g., physical violence, illegal possession, larceny, vandalism) at school compared to schools with less natural cafeteria window views and landscapes with fewer natural elements (e.g., fewer trees and shrubs, and more mowed grass or parking lots; Matsuoka, 2010). Additional relevant research has been conducted in preschool settings. For instance, when schoolyards were characterized by a greater level of natural elements (e.g., proportion of trees / shrubs, total outdoor area, and integration of vegetation with play structures), students were rated by staff as less inattentive, hyperactive, and impulsive (Martensson et al., 2009). Similarly, preschool students were rated by teachers as having greater reductions in behavioral challenges when schools were near high levels of tree canopy (Scott et al., 2015). Overall, the literature suggests that students may exhibit fewer behavioral challenges in schools with greater nearby nature (i.e., higher levels of vegetation or green space).

1.2.C Nature Exposure and Academic Achievement

Relative to the work exploring the potential connection between nature exposure and behavioral challenges for school children, even fewer studies have investigated associations between nature exposure and academic achievement. Given that behavioral challenges and academic achievement are highly interrelated (Fleming, Harachi, Cortes, Abbott, & Catalano, 2004; McIntosh, Flannery, Sugai, Braun, & Cochrane, 2008), it is likely that academic achievement is also associated with nature exposure.

Furthermore, consistent with the notion that nature exposure may yield benefits for children’s academic performance, children’s heightened cognitive functioning associated with nature exposure has been relatively well documented. However, results of studies investigating the potential benefits of nature exposure for academic functioning have been mixed. Multiple studies have documented that school-aged children improve substantially in performance on cognitive tests for concentration and attention following walks in the park, compared to urban or neighborhood walks (Schutte et al., 2015; Taylor & Kuo, 2009). In contrast, no improvements in students' attention were found in a quasi-experimental study examining the benefits of a broad-based intervention in Austrian schoolyards that added 20 shrubs and plants, as well as water fountains, seating, and recreational space (Kelz et al., 2013). Nevertheless, it is generally recognized that nature exposure can impact cognitive functioning (Kaplan, 1995; Ulrich, et al., 1991), an effect that is expected to contribute to academic achievement.

Some explicit efforts to connect nature and academic achievement have grown out of non-traditional programs such as forest schools and school gardens, yet most of the supporting evidence is anecdotal (Ozer, 2007; Slade, Lowery, & Bland, 2013). Those intervention approaches emphasize instruction and knowledge acquisition in outdoor environments as well as students' physical engagement with natural elements. Generally, it is expected that such outdoor experiences can support learning, language, and communication (Gill, 2014; Lovell et al., 2010), and there is some evidence to suggest that students can perform better academically when taught outdoors instead of indoors (Russell et al., 2013). Moreover, school gardens or forest schools can intentionally and explicitly use nature as a means for engaging students in active, hands-on learning of traditional course content from sciences and mathematics (Ozer, 2007; Slade et al., 2013). Although these non-traditional programs inherently change the approach to teaching and learning as a matter of course, and the research on these interventions differs substantially from the current study's emphasis on nearby nature in traditional school contexts, the broader literature provides additional context for how nature exposure might be leveraged to enhance academic achievement.

Five studies were found in the present review that investigated the link(s) between nature exposure and academic performance in the context of traditional schools; results from these are mixed, which may reflect differences in methodologies and selected samples. For instance, two studies examined benefits related to indoor plants and yielded contrasting results. One, a quasi-experimental study in Taiwanese classrooms, found that students in classrooms containing several small trees performed slightly better academically; however, these academic differences were not significant (Han, 2009). The other, involving South Australian middle school students, found that youth improved most in math, spelling, and science when plants were placed in their classrooms (Daly, Burchett, & Torpy, 2010); however, these results should be interpreted cautiously because there appeared to be differences favoring the intervention classrooms at baseline. Another relevant study assessed differences among college students in a writing course and demonstrated that students in classrooms with natural views, compared to those with views of a retaining wall, had higher end of course grades. Notably, these differences were not apparent mid-semester, only in the second half of the term, which may be explained by the rejuvenation of plants that occurred with the spring season (Benfield et al., 2005). The relevance of this work for the current study should also be framed cautiously, given the developmental differences between primary school students and college students and the fact that college students typically spend considerably less time in a single classroom or building compared to primary school students.

The present review identified two studies with direct relevance to the current study, given that they investigated relationships between public school students' academic performance and nature near schools. One study assessed the level of vegetation near Massachusetts schools using Geographic Information Systems (GIS) and found that students performed better on standardized tests in English and math when their schools were nearby greater amounts of vegetation (Wu et al., 2014). The other study examined high school-level trends in southern Michigan and assessed nearby nature using observer protocols for natural window views and the level of vegetation in the landscape. After controlling for socio-economic status and demographic composition, this work (Matsuoka, 2010) found that schools with greater nature exposure had more students who earned merit awards, graduated, and planned to attend a four-year college. While these results are promising, there is a need to explore these relationships, and the factors and characteristics that might influence them, in other geographic regions and across a wide range of grade levels. The present study sought to enhance understanding of the potential relationship between nature exposure and academic functioning.

1.3 Theory of Change Guiding the Current Study

Although little research has explored how nature exposure near schools may promote academic functioning, the physiological and cognitive mechanisms described in key theories (i.e., Attention Restoration Theory and Psychoevolutionary Theory; Kaplan & Kaplan, 1989; Ulrich, 1983) are also expected to influence academic functioning. Figure 1 illustrates a conceptual model of factors thought to underlie the relationship(s) between nature exposure and academic functioning. While the present study did not seek to test specifically the full conceptual model, key constructs believed to contribute actively to the change processes are represented in the figure.

According to the theory of change reflected in this model, students' academic functioning is bolstered by strong cognitive processing and healthy regulation of the sympathetic nervous system; these factors are each enhanced by exposure to nearby nature. Considerable research has connected nature exposure to lower stress levels and better cognitive functioning (e.g., Chen, 2014; Faber Taylor & Kuo, 2009; Kelz et al., 2013; Roe & Aspinall, 2011; Ward Thompson et al.,2012), and students are more likely to excel academically under such circumstances (e.g., Alloway & Alloway, 2010; Visu-Petra, Cheie, Benga, & Miclea, 2011). For instance, students' academic performance is weaker when they experience heightened levels of physiological stress reactivity, as indicated by heart rate and respiration rate (Vitasari et al., 2011), salivary pH (Cohen & Khalaiaes, 2014) and salivary cortisol (Lindahl, Theorell, & Lindblad, 2005). Furthermore, evidence points to a bi-directional relationship between physiological indicators of stress and cognitive functioning (e.g., alertness, attention, working memory, processing speed; e.g., Kaplan, 1995; Maldonado et al., 2008), which may impact academic functioning beyond cognitive or stress reduction processes operating in isolation.

In addition to these cognitive and physiological effects, it is expected that socio-emotional functioning and behavioral control may indirectly influence academic achievement. A growing body of research suggests that socio-emotional functioning supports greater academic achievement (Arnold, Kupersmidt, Voegler-Lee, & Marshall, 2011; Graziano, Reavis, Keane, & Calkins, 2007; Hasselhorn et al., 2015; Ursache, Blair,

& Raver, 2012), and a developing base of studies has established that children exposed to natural environments tend to exhibit greater mental and emotional health (e.g., Gill, 2014; Roe & Aspinall, 2011; Scott et al., 2015). Furthermore, behavioral problems are strongly associated with worse academic achievement (e.g., Eisenberg et al., 2005), and some research has demonstrated that children tend to exhibit fewer problem behaviors in more natural settings (e.g., Faber Taylor & Kuo, 2006; Scott et al., 2015; Wells & Evans, 2003). Overall, although the research exploring the contribution of nature exposure to academic and behavioral functioning in the school context is not well-developed, the existing literature points to several plausible mechanisms, including cognitive functioning, physiological stress responses, and socio-emotional functioning, through which nature might affect students' academic functioning, informing the theory of change guiding this work.

1.4 Operationalizing Nature Exposure for the Current Study

The existing research base regarding the potential benefits of nature exposure is difficult to interpret, primarily due to the diverse operational definitions for nature exposure employed in the extant literature. In general, nature is defined by physical features of non-human origin (Hartig et al., 2014); however, a single study may examine a specific aspect of nature exposure, and its findings may be inconsistent with studies focusing on a different aspect (or more than one element) of nature exposure. The present study aims to examine objective indicators of "nearby nature" (i.e., near key settings such as homes and schools; Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment, 2004, p. 79; Wells &

Evans, 2003). The following section describes how the conceptualization of nearby nature contrasts with the range of indicators that can be used to assess nature exposure.

"Wild nature" (Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment, 2004, p. 25) emphasizes natural settings without evidence of human influence or built environment. Forest schools embrace wild nature by providing outdoor education and learning opportunities via classes held in forests as opposed to traditional classroom settings; this form of outdoor learning may result in improvements in socio-emotional functioning of children (Lovell et al., 2010; Roe & Aspinall, 2011), but it may also be impractical to bring to scale in mainstream public schools.

In contrast, natural elements often exist in built or urban environments near spaces frequented by people (e.g., Hartig et al., 2014). As such, intervening via nearby nature may enhance key settings that are part of everyday environments. The present study focuses on nearby nature because this research has the potential to inform greening strategies in traditional school and program settings.

An inherent assumption regarding the exploration of benefits related to nearby nature is that passive nature exposure (e.g., green space is visible from windows) may yield benefits regardless of an individual's level of active engagement with or attention to natural elements. In fact, research indicates that both forms – active engagement or attention and passive exposure – can elicit acute health responses (Shanahan et al., 2015). Nature exposure has been described as involving three possible levels of engagement (Pretty, 2004): viewing (i.e., seeing nature through a window or images), incidental exposure (i.e., being in the presence of nature during activities), and direct participation in nature (i.e., activities that involve nature such as gardening). There is empirical support for the benefits of nature exposure at all three levels (Pretty, 2004), including when direct exposure is minimal. For example, relative to those with views of a brick wall, surgical patients who have views of trees from hospital windows have been found to exhibit superior recovery (Ulrich, 1984). Natural window views may also promote greater job satisfaction and work ability (e.g., Lottrup, Stigsdotter, Meilby, & Claudia, 2015), better behavior among children (e.g., Wells, 2000), and high school students' academic success (Matsuoka, 2010) and stress recovery (Chen, 2014).

Despite the potential benefit of passive exposure to nearby nature, most studies involving children investigate the benefits of active engagement with nature. In fact, a systematic review of research on the benefits of nature in everyday environments to children under age 12 found few studies in which engagement was not emphasized (Gill, 2014). This suggests that there may be a research bias toward investigating active forms of nature engagement among children. While awareness of nature appears to yield benefits (e.g., Dzhambov, in press; Lin, Tsai, Sullivan, Chang, & Chang, 2014), these conclusions largely rely on virtual stimuli (e.g., quick flashes of natural imagery) or do not account for variations in actual nature exposure. In fact, one study (Lin et al., 2014) found that benefits of nature exposure were only apparent when participants were aware of the exposure (i.e., not solely subliminal exposure to images); however, their exposure was virtual (using quick flashes of pictures), an experience that is theoretically and empirically distinct from actual nature exposure. It has also been noted that trees' impact on air quality may contribute to health and well-being (Hartig et al., 2014), which would occur regardless of one's awareness. Moreover, studies demonstrate that the effects of actual nature exposure are more profound than those for virtual nature exposure (Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009; Russell et al., 2013), suggesting that factors beyond readily observable stimuli (e.g. visual, auditory) likely contribute to the observed effects. Such findings challenge the notion that awareness alone is necessary for realizing nature-related benefits.

While awareness was not a focus of the current study, it warrants mention because efforts investigating nearby nature likely yield different implications for intervention compared to studies that emphasize active engagement and awareness. Investigating objective indicators of nearby nature could contribute to recommendations for greening interventions (e.g., planting trees), which increase passive nature exposure among those in the intervention setting (e.g., students and teachers in schools). Because nature exposure in greening interventions is passive, these would likely require fewer demands on teachers' and students' time for implementation compared to instructor-guided interventions that require active student engagement. For example, school garden programs may promote a number of positive outcomes for students; however, these programs also bring challenges for implementation that relate primarily to limited resources, including financial and human capital (Ozer, 2007). Similarly, existing demands on teachers and students limit the time available for implementing such interventions, a common barrier to sustaining school gardens (Ozer, 2007). Such logistical limitations underscore the general need to better understand the effects of nearby nature (Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment, 2004), which could yield implications for increasing the presence of natural elements near schools.

Differences in foci between active and passive interventions may have further implications for how nature exposure is operationalized and measured, leveraging either subjective or objective indicators (Hartig et al., 2014). Active engagement interventions often emphasize subjective experiences (e.g., awareness, interaction), whereas greening interventions aim to increase “objective” factors such as the volume or quantity of greenspace. Therefore, greening interventions may be best informed by objective assessments of nearby nature.

That said, although objective measurement tools may provide additional empirical rationale for greening interventions, there is variability in the methods of data collection across studies. Some studies use observer protocols (e.g., Wells, 2000) and provide a level of detail (e.g., number of plants visible from a window) that is not feasible for population-level studies; however, the use of GIS and aerial photography can quantify objectively the presence of natural elements at scale (e.g., Balseviciene et al., 2014; Scott et al., 2015; Wu et al., 2015). Furthermore, objective indicators vary by the type of nature investigated; many studies examine the presence of trees, and some investigate open green spaces (e.g., lawn), but few studies assess the role of impervious surface (i.e., human-made built structures that water cannot pass through; e.g., concrete and buildings; e.g., Scott et al., 2015) as a proxy for a lack of green space.

Among studies examining objective indicators of nature exposure, there is a need for further research that can help identify the types of nature that can have the greatest effectiveness in promoting specific developmental or adjustment outcomes (e.g., trees versus green space; Hartig et al., 2014). These distinctions were quite relevant in a recent study (Scott et al., 2015) that found that preschoolers exhibited the greatest improvements in behavioral and emotional regulation when there were high levels of tree canopy in either home or school neighborhoods. In that same work, preschoolers' social functioning and ability to initiate goal-oriented tasks improved least when students from low-impervious surface home neighborhoods were exposed to high levels of impervious surface in their school neighborhood (Scott et al., 2015). It is clear that additional work is necessary to enhance understanding of the potential benefits yielded by different types of nature exposure.

In addition to reflecting different types of natural elements (or their absence), metrics may differ based on their precision of measurement (e.g., aerial photography) or in the use of advanced indicators such as red and infrared light (e.g., Balseviciene et al., 2014; Wu et al., 2015). The vast majority of research uses crude distinctions between experimental conditions or relies on imprecise measurements; these issues limit understanding of relationships involving a diverse range of exposure levels (Shanahan et al., 2015). The current study aims to investigate outcomes related to the presence of both trees and impervious surface using relatively precise aerial photography estimates.

In sum, little research has explored or quantified students' academic benefits related to nearby nature, and the knowledge base can be enhanced through the use of population-level, objective assessments that quantify nature near key settings (e.g., schools). Research on nearby nature may highlight potential implications that differ from those yielded by research on interventions that emphasize wilderness settings or active and attentive engagement with natural elements, and may be more pragmatic and efficient to implement. The intent of the present study was to investigate the extent to which additional natural elements (defined objectively by the presence of trees or absence of impervious surface) near schools might contribute to students' academic functioning; thus, the implications were expected to align with school-yard improvement or greening efforts rather than staff-facilitated experiential interventions.

1.5 Exploring the Most Efficient Dosage of Nature Exposure

While evidence supports that individual functioning improves with nature exposure, limited research has investigated the level of nature exposure necessary for maximizing benefits (Shanahan et al., 2015). In theory, there may even be circumstances in which an excessive level of nature exposure could cause harm. For example, extremely "complex" (e.g., multiple layers, shapes, dimensions) and crowded vegetation could conceivably diminish benefits by increasing perceived stress (Shanahan et al., 2015). That said, any detrimental impact associated with excessive nature exposure has yet to be demonstrated (e.g., Shanahan et al., 2016), and in general, the potential risks of nature interventions (e.g., harm, resource loss) are thought to be less serious compared to other interventions (e.g., medical; Frumkin, 2013). Moreover, any potential risks are particularly diminished in urban areas in which spatial constraints limit the possibility of extremely high levels of dense vegetation (Shanahan et al., 2015). Nevertheless, there is a need to examine further patterns of relationships that enhance our understanding of the "dose" or quantity of nature that could contribute to maximal benefits and be cost effective (Hartig et al., 2014).

Dose-response modeling, a quantitative approach that can serve as a framework for assessing the optimal dose of nature, can be used to develop guidelines regarding the minimum dose of different types of nature that could be expected to yield health-related benefits (Shanahan et al., 2015). Examining nature exposure in this way can facilitate the development of straightforward recommendations for planning urban green spaces. There are several aspects of dosage that could be measured, including duration (i.e., length of time), intensity (i.e., diverse indicators of "how much", including quantity, such as counts, volume, percentage of vegetation cover, and quality, such as richness of bird species, number of habitats, and other characteristics), and frequency (i.e., "how often") of nature exposure. Existing research suggests that psychological well-being improves rapidly even after short durations of exposure, but little is known about the optimal dose of nature exposure intensity (e.g., foliage volume; Shanahan et al., 2015, p. 478). In the present study, the frequency and duration of the dose were held relatively constant across subjects because students attend schools on similar schedules. A primary aim was to quantify nearby natural elements (i.e., proportion of land covered by tree canopy and permeable surface, the latter indicating potential green space), an aspect of intensity, to assess the optimal dose of natural elements near schools.

The research to date does not specify anticipated dose-response trends for academic outcomes; therefore, it is not known whether academic functioning may continue to improve, remain relatively unaffected, or diminish in absolute terms after a particular threshold of nature exposure has been reached. Shanahan and colleagues (2015) describe four different types of curvilinear trends that could occur in dose-response models, which vary based on the degree to which those effects occur immediately, are maintained, plateau, or diminish following a high threshold of nature exposure. Health and behavioral responses are expected to exhibit a plateau trend, or ceiling effect, such that increasing levels of vegetation may have little or no incremental benefit after a threshold has been reached (Shanahan et al., 2015).

Few studies (see, e.g., Jiang, Li, Larsen, & Sullivan, 2016; Wells & Evans, 2003 for exceptions) have examined ceiling effects of nature exposure, and their results do not strongly support a ceiling effect. Nevertheless, varying measurement strategies, samples, and approaches make it difficult to conclude that there is no ceiling effect for high levels of nearby nature. For instance, one study investigating relationships between home nature and rural children's self-reported psychological distress and self-worth found no evidence of a ceiling effect (Wells & Evans, 2003); however, their nature assessment was limited, excluding greenspaces adjoining or near children's homes, which could have provided additional variability for detecting curvilinear trends. Another study investigated stress recovery among adults who viewed 3-dimensional videos of streets with varying levels of tree foliage density, and found that there was a significant curvilinear trend; however, the authors did not interpret that trend. They dismissed the result because the model fit was best explained by a constant (i.e., linear) relationship such that participants in the experiment reported greater recovery from induced stress when exposed to images of dense street trees (Jiang et al., 2016). A third, recent effort explored preschoolers' socio-emotional and behavioral outcomes associated with differing quantities of nature exposure in home and school neighborhoods (Scott et al., 2015). Although that study did not examine a curvilinear dose-response relationship, the findings suggested that there may be a ceiling effect because there appeared to be little incremental benefit of having high levels of tree canopy both at home and school; children improved most when they were exposed to high levels of tree canopy in at least one setting (Scott et al., 2015).

Notwithstanding the contributions of those three studies exploring optimal doses of nature exposure among children, the literature base on the dose-response of nature exposure is fairly underdeveloped. The dearth of literature is particularly noteworthy because the impact of small-scale interventions (e.g., in the classroom or schoolyard, compared to neighborhood-level) could be underestimated or undetected if plentiful nearby nature negates the benefits of a small-scale intervention. Put another way, some null results could conceivably be explained by a relatively lush nearby environment if there is a point at which additional nature exposure yields little incremental benefit. For example, a multi-pronged Austrian schoolyard intervention (an element of which was the addition of about 20 plants) did not yield improvements in students' cognitive functioning; however, authors noted that there was plentiful exposure to green space just beyond school grounds (Kelz et al., 2013). Therefore, a few additional plants may have not had a meaningful impact in the context of plentiful green space in the surrounding area. Furthermore, it may not be common practice to note the broader context of green space. For instance, authors did not describe the nearby greenspace in relation to a Taiwanese classroom-level intervention, which did not yield differences in academic performance between students in experimental (i.e., containing several small cinnamon trees) and control classrooms (Han, 2009). Additional research investigating ceiling effects of nearby nature may help guide the extent to which future research should account for or describe nearby nature.

1.6 Exploring the Possibility that Some Students may Benefit More than Others

Because (a) groups that tend to experience economic hardship, oppression, and other adversities disproportionately evidence dysregulation of physiological stress responses (e.g., Friedman, 2011), and (b) the benefits of nature exposure appear to be largely related to reduction of the physiological stress response (e.g., Ulrich, 1983), it was expected that groups facing higher rates of adversity would exhibit relatively better academic functioning in the context of nature exposure. In fact, nature exposure appears to buffer the effects of adversity by reducing the impact of stress (Corraliza Collado & Bethelmy, 2012; Hartig et al., 2014; Shanahan et al., 2015; Wells & Evans, 2003). Of note, studies have found that children who experience the highest levels of adverse conditions and stressful events benefit most from nature exposure (Corraliza Collado & Bethelmy, 2012; Wells & Evans, 2003).

The current study sought to explore whether children who were part of groups that tend to experience heightened levels of stress and adversity (e.g., those of racial minority backgrounds, children with disabilities or special needs, or those from low-SES backgrounds) exhibited heightened academic functioning in relation to nearby nature exposure. This study assessed whether disparities in academic functioning were less pronounced in school contexts with greater nearby nature exposure. Groups examined included those that tend to experience heightened levels of adversity (including Black[1] students, students with disability status, and students in high-poverty schools) and those who may be differentially impacted by adversity (including students of different ages, genders, and socio-cultural backgrounds).

Experiences of adversity are influenced by a number of social and contextual conditions, including the influence of prejudice, discrimination, and oppression based on one's position in the social hierarchy, which is influenced by individual characteristics such as race, ethnicity, gender, and social class (as well as broader factors such as culture and history; Garcia Coll et al., 1996; Kloos, Hill, Thomas, Wandersman, & Elias, 2012). Discrimination, or mistreatment tied to aspects of an individual's identity, reduces psychological well-being (e.g., increases in depression and distress; Schmitt, Branscombe, Postmes, & Garcia, 2014) and contributes to disparities in developmental competencies such as cognitive, social, emotional, and linguistic development (Garcia Coll et al., 1996). Further, the impact of discrimination is particularly profound among stigmatized groups, including those suffering from mental illness or physical disability (Schmitt et al., 2014).

As one example, research has established that Black youth regularly experience discrimination (i.e., at least once a year), which is associated with poor physiological (e.g., allostatic load, blood pressure), psychological (e.g., depression, anxiety), and behavioral (e.g., aggression, conduct) outcomes (Jones & Neblett, 2016; Pachter & Garcia Coll, 2009). Furthermore, relative to those representing other racial or ethnic groups, Black individuals tend to experience the greatest number of traumatic life experiences (Hatch & Dohrenwend, 2007) and the highest level of physiological stress response (Peek et al., 2010). These adverse conditions (and their effects) contribute to disparities in academic functioning (Levy, Heissel, Richeson, & Adam, 2016), and it was expected that these disparities would be minimized in the context of greater nature exposure.

Similarly, youth with disabilities and special needs are more likely to experience adversity than their peers without special needs, including discrimination, social exclusion, bullying, and harassment, which relates to poorer well-being above and beyond levels that are expected due to disability alone (Savage, McConnell, Emerson, &

Llewellyn, 2014). In light of these challenges, it was expected that academic disparities for children with disability status would be less pronounced when there was more nearby nature. In particular, it was expected that children with disability statuses related to emotional and behavioral disturbances may benefit most from nature exposure, a finding that would be consistent with prior research describing emotional and behavioral improvements among children attending a forest school (Roe & Aspinall, 2011).

Similar to the trends observed among individuals from minority backgrounds, individuals whose family circumstances reflect low SES tend to experience more stressful or traumatic experiences relative to their more socioeconomically-advantaged counterparts (Hatch & Dohrenwend, 2007). SES-related disparities are well documented for both physical and mental health-related outcomes and can be attributed, at least in part, to greater levels of stress and adversity experienced by individuals from low-SES backgrounds (Luthar, 1999; Reiss, 2013; Williams, Priest, & Anderson, 2016).

Of particular relevance to the current study, research examining nature as a moderator that buffers the impact of SES on health-related outcomes has been mixed. At the population level, researchers have documented fewer income-related disparities in England's mortality rates in greener residential areas (Mitchell & Popham, 2008). Similarly, a study involving Lithuanian preschool students found that the benefits of nearby parks and greenspaces were dependent on the level of education of children's mothers. More specifically, nature exposure predicted more prosocial behavior and fewer behavioral challenges among preschoolers with mothers with low educational attainment, whereas nature exposure was related to greater behavioral problems and fewer prosocial behaviors among preschoolers of mothers with high educational achievement

(Balseviciene et al., 2014). In contrast, another study investigated the relationship between greenspace and academic performance and found no additional benefits of nature for students in schools characterized by low compared to high family income (Wu et al., 2014). In the present study, in light of the theoretical work guiding this effort, as well as prior research findings, it was expected that disparities attributable to SES (aggregated at the school-level) would be lower among students in schools with plentiful nearby nature.

While some groups experience heightened levels of adversity and stress exposure, other groups may be less impacted by adversity compared to others. For example, children of different ages are likely to experience different levels of stressors (Hatch & Dohrenwend, 2007), exhibit different patterns of interpretation of and coping with traumatic experiences (Janoff-Bulman, 1992; Kilmer & Gil-Rivas, 2010), and evidence variability in their physiological responses (Gunnar & Quevedo, 2007). While cumulative exposure to stressful life events likely increases with age (Hatch & Dohrenwend, 2007), younger children may also exhibit less heightened physiological stress reactivity to stressful life events compared to adolescents, which may explain the increase in incidences of psychopathology among adolescents (e.g., higher rates of onset of emotional disorders and externalizing behavior problems during adolescence; Gunnar & Quevedo, 2007).

Few studies have explored potential age-related differences in responses to natural stimuli. As one case in point, one study (Schutte, Torquati, & Beattie, 2015) assessed the degree to which preschool- and school-aged children evidenced differential cognitive benefits of a nature walk, compared to an urban walk. Results showed that school-aged children improved more in attention, whereas preschool children improved more in working memory, following the nature walk (Schutte et al., 2015). These mixed patterns of age-related cognitive effects raise questions regarding which age group might show the greatest academic benefits associated with nature exposure. For the current study, based on developmental patterns regarding response to adversity, it was hypothesized that older students in schools with greater nearby nature would evidence even more pronounced effects in their academic testing performance, exceeding typical differences in performance attributable to grade level. It was also expected that the tendency for older children to exhibit more problem behaviors would be less pronounced in schools with more nearby nature.

Experiences of adversity and related outcomes also vary by gender. Not only do the types of stressful or traumatic life events vary between males and females (Hatch & Dohrenwend, 2007), there are differential outcomes by gender (i.e., in the way in which children manifest their distress), as boys tend to experience greater externalizing problems and girls tend to experience greater internalizing problems (Leadbeater, Kuperminc, Blatt, & Hertzog, 1999). Because nature exposure may reduce externalizing symptoms by ameliorating stress responses, it was expected that males' tendency toward heightened levels of externalizing behavior problems would disproportionately diminish with greater nearby nature. Studies examining gender differences in response to nature exposure have yielded mixed results, but most suggest that males are more likely to benefit from nature than females on tests of cognitive functioning, hyperactivity and inattention ratings, as well as health-related mortality rates (e.g., Markevych et al., 2014; Richardson & Mitchell, 2010; Schutte et al., 2015). In contrast, other studies have found no differences between males and females (Wu et al., 2014) or found that females improved more on cognitive testing when there was more nature viewable from their home (Faber Taylor et al., 2001). The present study hypothesized that the propensity for boys to have greater behavioral problems (as indicated by discipline records and days suspended) compared to girls would be diminished in schools with greater nearby nature; however, the current literature did not guide a specific hypothesis regarding possible gender-related differences in academic testing performance in response to greater nearby nature exposure.

Immigrant children represent another group that may experience unique patterns of adversity and corresponding outcomes (e.g., Degboe, BeLue, & Hillemeir, 2012). A number of studies have found that immigrants tend to exhibit higher levels of psychological and physical well-being compared to native-born US citizens, despite risk factors such as poverty and discrimination (Kolker, 2011). Corroborating evidence comes from studies that have found the lowest levels of physiological stress reactivity among foreign-born Mexican Americans compared to US-born adults (Peek et al., 2010), and greater academic and behavioral functioning among youth with immigrant parents compared to youth with US-born parents (Chun & Mobley, 2014; Degboe et al., 2012). Immigrant students have been found to be less susceptible to risks associated with poverty, and more likely to experience higher levels of potential protective factors such as a school belonging and family connectedness (Chun & Mobley, 2014). However, these advantages do not appear to apply evenly across groups of immigrants. For example, adolescent immigrants are particularly at risk for exposure to psychosocial stressors, exhibiting higher levels of psychological distress and drug use compared to native-born peers (Teruya & Bazargan-Hejazi, 2013). While it is expected that immigrant status may play a protective role for some youth, the evidence is mixed. This study sought to investigate socio-cultural differences by assessing the degree to which nature exposure has a bearing on outcomes associated with being a student who is limited in English proficiency (LEP). LEP status was used in the current study as a proxy for immigrant status, and it was speculated that this group may experience some of the protective benefits associated with immigrant family background. As such, it was hypothesized that the academic performance of students with LEP classifications would be less influenced by nature exposure compared to English-speaking students.

1.7 The Context of the Present Study

The present study sought to examine the relationships between nearby nature exposure and academic functioning, including academic performance and behavioral incidents, among elementary and middle school students (i.e., kindergarten through eighth grade) in Charlotte Mecklenburg Schools (CMS). Schools were situated in an urban region that includes areas that are urban and suburban. In 2013-14, this school system was comprised of 165 schools with 142,991 total students, with an average student teacher ratio of 16.51:1 (National Center for Educational Statistics, n.d.). Enrolled students were of diverse ethnic and racial backgrounds, as approximately 70% of students were non-White in 2013-14; however, nearly half of White students attended schools that were majority White, which has led to critiques regarding the segregation of children of color in high-poverty schools that are majority non-White (Helms, 2014). Nonetheless, CMS has also received recognition for the improvements that have been made in reducing the academic achievement gap (e.g., the greatest recent gains in math and reading have been among Black and Hispanic students) and has highlighted marked improvements in graduation rates from 2010 to 2014 across all demographic subgroups of students (CMS, n.d.-b). Compared to several other urban public school systems, CMS students have performed better on reading and math standardized tests (CMS, n.d.-b).

In addition to Charlotte-Mecklenburg's achievements within the public school system, this growing urban region has been acclaimed for its high levels of tree canopy (Stabley, 2013). The city has been recognized as a Tree City USA by the Arbor Day Foundation for 35 years in a row and, in 2013, was recognized by American Forests as one of the top 10 urban forests in the nation (Israel, 2016). Even though Charlotte has been praised for its tree canopy, the city is one of the fastest growing cities in the country, which presents challenges for maintaining and growing tree canopy because development efforts often bulldoze mature trees to make room for new construction. In fact, city stakeholders became alarmed by trends that indicated that tree canopy had declined from 48 to 46 percent of total land area between 2002 and 2008, prompting the development of the initiative "50 by 2050", which seeks to plant and maintain tree canopy to reach 50% canopy by the year 2050 (Israel, 2016). This effort works with nonprofits, neighborhoods, private property owners, schools, faith institutions, public housing projects, and other community stakeholders to engage in tree plantings as well as tree preservation efforts (Israel, 2016). While there have been substantial tree planting efforts at some CMS schools (e.g., CMS, n.d.-d.), staff in Mecklenburg County's Landscape Management division have noted that not all schools are interested in planting events, as some school leaders have been reluctant to increase the presence of trees on school grounds due to concerns about liability (e.g., child or parent could be injured by debris) or increased maintenance costs (Oliverio, E., personal communication, June 11, 2015). The presence of tree canopy is further imbalanced across locales – tree canopy is disproportionately available in areas that include generally higher-income neighborhoods, particularly in south and east Charlotte, and lacking in areas that have recently seen extensive development (Israel, 2016).

1.8 Statement of Purpose and Research Questions

The present study sought to build on the existing literature base that has unequivocally documented physiological and cognitive benefits of nature exposure, but is underdeveloped in the extent to which nature's linkages with behavior and academic achievement have been examined in the school context as well as in the degree to which potential differential effects have been examined across children from varying backgrounds. The study also sought to utilize local data as a tool that may inform change efforts, as it was expected that results may suggest implications for enhancing the presence of vegetation and tree canopy nearby school grounds in Mecklenburg County. These objectives were carried out by investigating public school student academic functioning (i.e., academic performance and disciplinary incidents) across elementary and middle schools that vary in the degree to which students were exposed to natural elements (e.g., trees, green spaces).

The current study also sought to understand the level of nature exposure that may most cost-effectively maximize student academic functioning through dose-response modeling (Shanahan et al., 2015). Understanding an optimal dose of nature exposure could inform the level of nearby nature that schools should aspire to cultivate. Results were also expected to contribute to a limited literature base, as was the exploration of nature exposure's potential for reducing disparities in academic functioning. Better understanding how nature exposure might contribute to the academic functioning of disadvantaged students may provide guidance to schools and districts about strategically cultivating greenspaces (e.g., targeting schools that have high proportions of students who are apt to benefit from nature exposure with greening interventions).

The following research questions and hypotheses guided the current work's exploration of the relationship between academic functioning and nature exposure nearby public schools:

1. To what extent is nature exposure related to academic functioning? (Figure 2)

   Hypotheses:

   a) Students in schools with greater nearby tree canopy will perform better on standardized tests compared to students in schools near less tree canopy.
   b) Students in schools near greater nearby tree canopy will exhibit fewer problem behaviors, as indicated by disciplinary referrals and suspensions, compared to students in schools near less tree canopy.
   c) Students in schools with greater nearby permeable surface will perform better on standardized tests compared to students in schools near less permeable surface.
   d) Students in schools with greater nearby permeable surface will exhibit fewer problem behaviors, as indicated by disciplinary referrals and suspensions, compared to students in schools near less permeable surface.

2. What “dose” of nature exposure is associated with optimal academic functioning? (Figure 3)

   Hypotheses:

   a) The benefits to standardized testing associated with tree canopy will plateau and reach a ceiling such that, once a certain threshold (investigated and identified by this project) has been reached, additional tree canopy will be associated with little additional benefit.
   b) The behavioral benefits associated with tree canopy will plateau and reach a ceiling such that, once a certain threshold (investigated and identified by this project) has been reached, additional tree canopy will relate to little additional benefit.
   c) Academic benefits associated with permeable surface will be most pronounced among children in schools with the lowest levels of permeable surface compared to students in schools with moderate or high levels of permeable surface.
   d) Behavioral benefits associated with permeable surface will be most pronounced among children in schools with the lowest levels of permeable surface compared to students in schools with moderate or high levels of permeable surface.

3. To what extent does the relationship between academic functioning and characteristics of the school or student vary as a function of nature exposure? (Figure 4)

   Hypotheses:

a) Academic disparities for Black students will become less pronounced when their schools are nearby nature.

b) Relative to LEP students, English proficient students (i.e., non-LEP status) will show disproportionately more academic benefits when their schools are nearby nature.

c) Adolescent students will disproportionately exhibit fewer behavior problems and perform better on academic testing, compared to younger students, when their schools are nearby nature.

d) Academic disparities for students with a disability status (i.e., exceptional child) will become less pronounced when their schools are nearby nature.

e) The propensity for male students to exhibit more problem behaviors compared to females will diminish when schools are nearby nature.

f) Academic disparities for students in high-poverty schools (i.e., higher rates of free and reduced lunch) will become less pronounced when schools are nearby nature.

CHAPTER 2: METHOD

2.1 Participants and Selection

The study sample was derived from 103,696 public school students who were enrolled in grades kindergarten through eight in the Charlotte-Mecklenburg School (CMS) system for the 2013-2014 academic year. To ensure that exposure to environmental conditions near schools was held constant across students in the study sample, students who did not attend the full year (defined by North Carolina Department of Public Instruction [2014], regarding proficiency testing and standards, as 140 days; n = 4,331, or 4.2%, did not meet this threshold) or who attended multiple schools (n = 4,670; 4.5%) were excluded from analysis. Students with missing age data or with ages outside the norm (i.e., median +/- 1 year) for their grade level (n = 37; < 0.01%), identified using a cross-tabs procedure, were also excluded from the sample. Students who were missing data for dependent variables were also excluded from the sample; few students were missing behavioral data (n = 2; < 0.01%), and a substantial proportion of students were missing testing data (n = 11,270; 10.9%). Students in two schools that were outliers due to having extremely high levels of tree canopy (n = 1,202; 1.2%) were also excluded. Furthermore, to eliminate confounds associated with atypical curricula or programs, which likely impact dependent variables (i.e., behavior and academic achievement), students in schools with magnet, Science-Technology-Engineering-Math (STEM), International Baccalaureate, alternative or other special program designations (n = 34 schools; n = 22,740 students; 21.9% of students) were excluded from analysis. These categories for exclusion were not mutually exclusive and, as such, the sum of students excluded as a result of each criterion exceeds the total number of excluded students. A total of 33,377 (36.0%) students were excluded from the study sample.

The selected sample was comprised of 66,319 students within 92 traditional public elementary or middle schools. Demographic characteristics of the selected sample are presented in Table 1. Analyses assessed demographic differences between the selected sample and those excluded. The large sample size inflated power such that it was necessary to interpret effect sizes for significant differences. There were several statistically significant but small differences detected between the selected and excluded samples. For instance, White students were disproportionately represented ($\Phi = -0.18$), and Black students were disproportionately excluded from the study sample ($\Phi = 0.18$). The exclusion of Black students was largely explained by disproportionate missing testing data compared to students of other racial and ethnic backgrounds; a number of factors contributed to the disproportionate representation of White students, including that they were more likely than non-White students to (a) attend only one school, (b) be enrolled in a traditional school, and (c) have complete testing data.

Students in the selected sample were also younger (Cohen's $d = -0.13$), on average, and tended to have fewer behavioral incidents ($d = -0.23$) compared to those excluded. These trends suggest that relatively low-functioning students (e.g., greater behavioral challenges; incomplete standardized testing) may have been disproportionately excluded from the selected sample. Together, these differences appear to suggest that the missing test scores were not missing at random, making the data unsuitable for multiple imputation of missing scores. Overall, the sample was not representative of the broader CMS student body, but represented students who attend traditional schools and were relatively average or high functioning. Selected students ranged in age from 4 to 15 years (*M* = 8.79; *SD* = 2.59; selected schools included 20 middle and 72 elementary schools) and, although they varied in urbanity, they largely (62%) were from schools within city limits. Moreover, the selected students reflected diverse ethnoracial backgrounds; a little more than one-third were White, approximately one-third were Black, and approximately one-fifth were Hispanic. Therefore, the sample appears to represent a relatively diverse, urban and suburban student population.

2.2 Measures

This study drew on secondary data collected by the school system (i.e., CMS) and the Landscape Management Division of the City of Charlotte. CMS regularly collects data on academic achievement through standardized testing and maintains records of disciplinary incidents and suspensions. The City of Charlotte periodically assesses Mecklenburg County's land cover, including tree canopy and impervious surface. The current study used these data to examine the relationships between nature exposure and student academic functioning. Further description of study variables is organized by levels of analysis – student and school levels.

2.2a Student–Level Variables

Demographic Characteristics: Student characteristics are routinely collected via CMS enrollment procedures, including gender, age as of the first day of classes for the 2013-14 academic year, race or ethnicity (note that the data provided by the school system collapsed race and ethnicity categories), limited English proficiency (LEP), and

Exceptional Child status, including disability status and status as academically and intellectually gifted (AIG).

Race/ethnicity were coded so that White students comprised the referent group, and students who are Black, Hispanic, or “other” (i.e., reflecting students of ethnic and racial backgrounds that are lowest in frequency in this sample) were dummy coded for analysis.

Limited English Proficiency (LEP) status is the classification assigned to students whose native language is not English. Most LEP students are Spanish speaking; correlations between LEP and Hispanic status (r = .62) were not strong enough to raise concerns regarding multicollinearity. The second most common language among LEP status students is Vietnamese (CMS, 2016). The current study assessed LEP status as a proxy for immigrant status without regard to first, second, tertiary, etc., generation migration.

Disability status was indicated by the “Exceptional Child” status (i.e., EC status) that CMS assigns to students receiving disability-related services as part of an Individualized Education Plan (CMS, n.d.-c). Although there are conceptually distinct categories that CMS uses to characterizes the nature of a students’ disability, the current study examines EC status as a whole (i.e., effects associated with EC, regardless of classification).

Academically and intellectually gifted (AIG) status is defined by CMS using multiple criteria, including informal assessments and achievement assessments. Although most students are tested and identified in second grade, the specific identification process varies across grade levels, and can be influenced by external testing results or alternative assessments (CMS, n.d.-a).

Academic Achievement: Measures of Academic Progress (MAP) is a formative academic assessment tool published by the Northwest Evaluation Association (NWEA, 2011). The MAP is computer adaptive, with items selected during an administration based on the accuracy of responses to prior questions, thereby tailoring the assessment to individual students' performance and ability. MAP scores are standardized to form the Rasch Unit Score (RIT; a standardized score of student achievement and growth), which ranges from 100 - 350 (NWEA, 2011). There is high internal consistency of the MAP, which is indicated by marginal reliabilities (comparable to Cronbach's alpha) that are appropriate for computer adaptive tests (i.e., every student gets a different set of questions every time the test is taken). According to NWEA national and state testing protocols, reliability indicators are above .90 for both math and reading, at each grade level, and across states (including North Carolina). MAP scores were aggregated by creating a mean of both scores for each child because correlations between math and reading were very high ($r = .93$).

The MAP is administered three times a year (fall, winter, spring). The current study used MAP RIT scores for reading and math, yielded from the test's spring (end of the year) administration in April. Performance on the end of year assessment was expected to be most sensitive to nature exposure because of potential seasonal differences (e.g. Paddle & Gilliand, 2016; Scott et al., 2015), and the fact that students had been exposed to the school environment over the course of the full academic year. The MAP assessment was selected as the primary indicator of academic performance because it is the only CMS assessment used with students in kindergarten through middle school (i.e., K-8th grade). Furthermore, research has demonstrated that the MAP is comparable to other measures of academic achievement required by the State of North Carolina (i.e., End of Grade Testing; NWEA, 2016).

Behavior Challenges: Data regarding students' behavioral incidents, suspensions, absences, and tardies are recorded through a centralized reporting system maintained by CMS. Behavioral incidents reflect the number of instances in which student infractions against the code of conduct were reported; a given incident may reflect a number of infractions. Those offenses vary in severity, ranging from minor transgressions and misbehavior (e.g., bullying, oppositionality, breaking school rules) to criminal behavior (e.g., drug possession) to dangerous or violent offenses (e.g., physical attacks). The study assessed the number of behavioral incidents as the primary dependent variable for behavioral challenges because suspension data were deemed unreliable due to the level of school administrator discretion in response to student misbehavior (e.g., some schools do not suspend or record consequences; as such, approximately half of schools reported an average of zero days of in-school suspension across students). It is noteworthy that there is also variability in enforcement of some school rules (e.g., some schools may more strictly enforce a dress code) as well as discretion in the recording of behavioral incidents (e.g., some teachers may be more prone to report noncompliance); hence, these data reflect reported instances of student misconduct at the discretion of teacher and school administrators (e.g., Gregory, Skiba, & Noguera, 2010), and may be influenced by school discipline practices or neighborhood conditions (e.g., Arcia, 2007; Irwin, Davidson, & Hall-Sanchez, 2013). The percent of days a student was absent was used as a control variable because it was anticipated that students would exhibit higher test scores and fewer behavioral incidents when they missed fewer days of school.

2.2b School–Level Variables

Nature Exposure: This study used two indicators of nature exposure – tree canopy (i.e., area of ground covered by tree foliage) and permeable surface (i.e., the inverse of impervious surface, which is defined as manmade materials that water cannot pass through, such as built structures and concrete). Data for both tree canopy and impervious surface were collected in 2012 using aerial photography and LiDar with 1-meter resolution imagery – this occurred via a project funded by the City of Charlotte, with assessments conducted by the United States Department of Agriculture's Forest Service (O'Neil-Dunne, 2014). Nature indicators reflect a proportion of land coverage; as such, the data were formatted as decimals (e.g., 0.5 indicates 50%; 1 indicates 100%).

School Characteristics: CMS provides aggregate data for each school regarding the school size, demographic composition, and the proportion of students receiving Free or Reduced Lunch (FRL). Data from the 2013-2014 school year were used. School-level SES was represented by FRL data. It is worthwhile to note that these data did not specifically reflect the median income of those whose children attend the school; rather, this information reflects the number of students whose parents sought out and applied for a government assistance program, and were approved based on self-reported income. In fact, the rates of students receiving FRL were so much greater in schools with a high proportion of Black students (r = 0.79), that the proportion of Black students was not included as a control variable due to concerns about multicollinearity, despite it being a strong school-level predictor of disciplinary outcomes (Skiba, Trachok, Chung, Baker, &

Hughes, 2012). However, another known school-level predictor of disciplinary outcomes (as documented in the broader literature) was included as a covariate – the number of students enrolled (Skiba et al., 2012). Additionally, covariates were added to account for differences between elementary and middle schools (i.e., middle schools were dummy coded as 1; three K-8 schools in the sample were coded as elementary schools) and between schools that were in or outside city limits (i.e., schools in city limits were dummy coded as 1).

2.3 Analytic Approach

Because the relationships between school nature exposure (Level-2 variable) and student academic functioning (Level-1 variable) were central to the current study, multilevel modeling (MLM) was used for analytic testing. This approach is well suited for investigating the importance of context by nesting Level-1 variables (i.e., student functioning and characteristics) within Level-2 (i.e., schools) to examine the potential influence of higher-level variables (Level-2) on lower-level (Level-1) outcomes (Luke, 2004). Most importantly, MLM is preferred when data are nested within shared groups to avoid violating the assumption of independence and inherent problems with disaggregation (e.g., when inferences about an individual are drawn from group level data; ecological fallacy) and aggregation (e.g., when inferences about a group are drawn from individual-level data; atomistic fallacy; Luke, 2004).

In addition to applying MLM to avoid violating assumptions of multiple linear regression, analyses investigating behavioral incidents adjusted for an abnormal distribution. These data were not continuous, but reflected counts of incidents; the distribution is highly skewed such that, relative to the total sample, few students had behavioral incidents on record. To adjust for this distribution, a negative binomial regression model was integrated into the multilevel equations that examined behavioral incidents. This approach is appropriate for count data that are over-dispersed, such that the means (i.e., 0.07-0.26 for these data in the present study) are much smaller than the variance (i.e., 0.36-1.88 here; Hilbe, 2007).

2.3a Spatial Analytics

In general, it was expected that indicators pertaining to students' immediate surroundings would be more sensitive to predicting student behavior compared to indicators at a broader population level (e.g., census tract; Santiago & Galster, 2014). However, a study with aims similar to those of the current study found that student academic achievement was more strongly associated with a more distal assessment of nature exposure (i.e., 2000-meter radius) compared to more proximal indicators (i.e., 250- and 500-meter radii) of nature exposure (Wu et al., 2014). The authors of that study speculated that the more distal assessment may have captured a greater range of students' exposure, including both school and residential settings (Wu et al., 2014).

Because the current study aimed to assess nature near schools to explore the potential benefit of schoolyard greening interventions, the most proximal indicators of exposure were of greatest interest (e.g., the average schoolyard size in several US cities is 1.0-2.5 ha, approximately 185-300 feet from the school; Schulman & Peters, 2008). However, to ensure that the selected nature indicators were adequately predictive, the first model explored the sensitivity of nature exposure indicators at three different distances – one tenth, one quarter, and one half mile, from the school. Models 2 and 3 incorporated the nature exposure indicators at the half-mile distance because that distance was most sensitive to dependent variable association in model 1 analyses (i.e., main effects).

Nearby nature was quantified using GIS software by plotting the coordinates of all sampled schools onto maps of tree canopy density and permeable surface. Using buffer zones around each school, each nature variable was quantified as a percentage of land coverage within a radius of one-tenth, one-quarter, and one-half mile of each school's coordinate. In addition to landscaping or natural areas of woods or grasses, land covered by athletic fields contributed to greater permeable surface, whereas roads and parking lots directly detracted from the amount of permeable surface calculated near schools. Using a map of Charlotte city boundaries, schools with coordinates falling inside city boundaries were coded as being located in city limits.

To inform the inclusion of independent variables and covariates in analysis, correlations between student-level indicators of academic functioning, student characteristics, and school-level nature exposure were assessed and are presented in Table 3. Correlations between student- and school-level characteristics should be interpreted cautiously because these violate the assumption of independence (i.e., many students attend the same school), which can contribute to inaccurate standard error estimations. Additionally, behavioral incident data violate assumptions because the distribution was skewed and over-dispersed, rather than following a normal curve with modest standard deviations. Furthermore, the large sample size inflated the power for detecting small associations, such that most correlations were significant.

Correlations between academic test scores and nature indicators were moderate, and relationships were opposite of the expected direction (i.e., greater tree canopy was related to lower MAP scores; greater permeable surface was related to lower MAP scores). Correlations between behavior data and nature indicators were very small; relationships involving tree canopy and behavior data were either nonexistent or were inverse to the expected direction (i.e., more behavioral incidents among students in schools near more trees). In contrast, the relationship was more consistent and of greater magnitude between permeable surface and behavioral data (i.e., fewer behavioral incidents among students in schools with more permeable surface).

Additional correlations at the school level revealed few significant relationships between nature and academic indicators (Table 4). Selected student outcome data (i.e., MAP scores and behavioral incidents) were aggregated at the school level to examine these relationships. Correlations between nature indicators were moderate (ranging from 0.29 to 0.55), but did not raise concern regarding multicollinearity. Nature indicators within one-tenth of a mile from the school were most strongly related to academic performance (i.e., MAP scores); however, these relationships were also opposite of the expected direction (i.e., greater tree canopy was related to lower MAP scores; greater permeable surface was related to lower MAP scores). These correlations also revealed differences in nature indicators across schools such that schools with greater numbers of enrolled students were near fewer trees and less permeable surface; elementary schools were near more trees and permeable surface; schools within the city limits were near more trees and less permeable surface; and schools with higher rates of poverty (i.e. greater FRL) as well as those with greater Hispanic and LEP populations were near more tree canopy. These relationships, particularly with regard to greater tree canopy near poorer schools, were unexpected. Also unexpected was that larger schools (i.e., greater number of enrolled students) had higher MAP scores and fewer students receiving FRL. There was a strong association between the percentage of Black students and students receiving FRL at the school level, which indicated multicollinearity and precluded the inclusion of the percentage of Black students in analyses as a covariate. Overall, the school-level correlations were strongest for one-tenth mile nature indicators; however, there were a number of unexpected patterns in the data that made these relationships difficult to interpret. Ultimately, final analyses used half-mile nature indicators because these were most strongly associated with student outcomes in the first complete model (i.e., testing main effect associations between nature and academic indicators).

2.3b Model Testing

Consistent with its primary aims, this study tested three models: (1) main effects between nature exposure and academic functioning, (2) ceiling or exponential effects of nature exposure on academic functioning, and (3) moderating effects of nature exposure on the relationships between individual- and school-level characteristics and academic functioning. Models 2 and 3 built on model 1, as main effects must be accounted for when testing quadratic effects (i.e., ceiling effect, model 2) and interaction effects (i.e., moderation, model 3).

It is important to note that the design for model 3 was selected because it was not analytically feasible to test Level-1 characteristics (e.g., students' race) as moderating the relationship between nature exposure (Level-2) and academic functioning (Level-1). Therefore, model 3 indirectly investigates which students benefit the most from nature exposure by examining nature as a buffer for adversity that disproportionately benefits certain groups of students (e.g., via reductions in disparities).

All multilevel models clustered students (i.e., Level 1) by school (i.e., Level 2) to control for interdependence among students attending the same school. Continuous Level-1 (i.e., attendance and age) and Level-2 variables (i.e., nature indicators, FRL, enrollment) were grand-mean centered to enhance interpretation. Models were tested sequentially, starting with the examination of simple, main effects (i.e., model 1). Subsequent models tested for more complex patterns of relationships while controlling for main effects.

To assess whether there was variance in the Level-1 outcome variable due to Level-2 factors, a null model analysis was conducted using HLM, Version 7 (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011) for each proposed dependent variable (Table 5). This model computes an Intraclass correlation coefficient (ICC) value, and indicated that 26-33% of the variance in individual student achievement variables (Level-1) were attributable to school characteristics (Level-2). This substantive amount of variance provided rationale for continuing with MLM because it demonstrated significant interrelationships between students attending the same schools. HLM7 was used for subsequent analyses.

To examine the main effects of Level-2 predictors (see Figure 2), tree canopy and permeable surface, on students' academic functioning, Level-2 predictors were entered into the intercepts-as-outcomes equation:

Level 1: $Y_{ij} = \beta_{0j} + \beta_{hj} \sum_{h=1}^{6} X_{hij} + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + \gamma_{01} G_j + \gamma_{02} H_j + \gamma_{03} I_j + u_{0j}$

$\beta_{hj} = \gamma_{h0}$

where Y_{ij} is the dependent variable for student i nested in school j (Y_{ij} is log-transformed for analyses examining behavioral incidents; Y_{ij} is not log-transformed for analyses examining MAP), β_{0j} is the level-1 intercept (i.e., estimated school-level mean) for student academic functioning nested in school *j*, β_{hj} is the difference on the estimated mean of female, Caucasian, non-LEP, non-EC, and non-AIG students (i.e., reference group) due to the level-1 covariate *h* (i.e., age, EC, AIG, male, LEP, Black, Hispanic, other race, and percentage of days absent) for school *j*, X_{hij} is the level-1 covariate *h* for student *i* nested in school *j*, r_{ij} is the residual component at level-1 (error term) that indicates the amount of variance not explained of the dependent variable in the model for student *i* nested in school *j*, γ_{00} is the mean of academic functioning for all students (i.e., grand mean), γ_{01} is the fixed effect of tree canopy on the estimated mean of reference group students after controlling for level-2 variance (i.e., school), G_j is the level of tree canopy for school *j*, γ_{02} is the fixed effect of permeable surface on the estimated mean reference group students after controlling for level-2 variance (i.e., school), H_j is the level of permeable surface for school *j*, γ_{03} is the fixed effect of FRL on the estimated mean of reference group students after controlling for level-2 variance (i.e., school), I_j is the proportion of FRL at school *j*, U_{0j} is the unexplained variance in the average academic functioning for school *j*, and γ_{h0} is the fixed effect of the level-1 covariate X_h across schools.

The second model explored the degree to which high levels of nature exposure are associated with incremental benefit to students' academic functioning by estimating a curvilinear trend between nature exposure and academic functioning (see Figure 3). This analysis was much like the first model because main effects were tested and the only terms added were quadratic terms for each of the nature exposure variables.

Level 1: $Y_{ij} = \beta_{0j} + \beta_{hj} \sum_{h=1}^{6} X_{hij} + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + \gamma_{01}G_j + \gamma_{02}H_j + \gamma_{03}I_j + \gamma_{04}G_j^2 + \gamma_{05}H_j^2{}_j + u_{0j}$

$\beta_{hj} = \gamma_{h0}$

where γ_{04} is the curvilinear effect of permeable surface on the estimated mean of reference group students after controlling for level-2 variance (i.e., school), G^2_j is the level of tree canopy for school squared, γ_{05} is the curvilinear effect of permeable surface on the estimated mean of reference group students after controlling for level-2 variance (i.e., school), and H^2_j is the level of permeable surface for school squared.

The third model examined either a school-level or one of five student-level moderators in separate analyses (see Figure 4). Equations for the school-level moderation and student-level moderation differed; however, both incorporate the same terms as model 1 with the addition of interaction terms. The following equation was used to examine FRL as a school-level moderator:

Level 1: $Y_{ij} = \beta_{0j} + \beta_{hj} \sum_{h=1}^{6} X_{hij} + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + \gamma_{01}G_j + \gamma_{02}H_j + \gamma_{03}I_j + \gamma_{04}G_jI_j + \gamma_{05}H_jI_j + u_{0j}$

$\beta_{hj} = \gamma_{h0}$

where γ_{04} is the interaction effect between tree canopy and FRL on the estimated mean of reference group students after controlling for level-2 variance (i.e., school), and γ_{05} is the interaction effect between permeable surface and FRL on the estimated mean of reference group students after controlling for level-2 variance (i.e., school). The next equation was used to examine potential student-level moderators (corresponding with Figure 4):

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + \beta_{hj}\sum_{h=1}^{5} X_{hij} + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + \gamma_{01}G_j + \gamma_{02}H_j + \gamma_{03}I_j + u_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{20}G_j + \gamma_{30}H_j$

$\beta_{hj} = \gamma_{h0}$

where β_{1j} is the differences on the estimated mean of reference group students due to the level-1 moderated variable (e.g., age, EC, male, LEP, Black) for school j, X_{ij} is the level-1 moderator for student i nested in school j, β_{hj} is the differences on the estimated mean of reference group students due to the level-1 covariate h (including all covariates except for the moderated covariate of interest) for school j, X_{hij} is the level-1 covariate h for student i nested in school j, γ_{20} is the fixed effect of tree canopy on β_{1j}, and γ_{30} is the fixed effect permeable surface on β_{1j}.

After analysis, significant results for higher-order effects (i.e., models 2 and 3; curvilinear and moderation effects) were interpreted by estimating the dependent variable (Y) associated with independent nature variables while holding all covariates constant by adjusting each to the mean (i.e., grand-mean centered variables were held at zero; non-centered variables were adjusted based on the mean of the covariate). This allowed higher-order trends between dependent variables and nature indicators to be graphed, depicting an estimate of student academic functioning at different levels of nature exposure.

Because estimates of behavioral incidents were log-transformed in analyses, interpreting the estimated betas in isolation yields relatively meaningless coefficients; therefore, interpretation of behavioral analyses was further enhanced by converting log-transformed estimates to incident rate ratios (IRR), which estimate the odds of a behavioral incident among students in schools with a specified level of nature relative to the estimated odds among students in schools with zero nature exposure. As such, graphs of behavioral incidents depict the odds of a behavioral incident relative to the students in schools with zero tree canopy, after controlling for covariates.

The final interpretive step computed pseudo R-Squares, which estimate the amount of variance accounted for by level-1 (i.e., student) or level-2 (i.e. school) predictors relative to the null model (which has no predictors). Pseudo R-Squares are an estimate of model fit as they depict the extent to which a model explains variance at each level.

CHAPTER 3: RESULTS

3.1 Relationship between Nature Near Schools and Students' Academic Functioning

To test the main effects of school nature, each dependent variable (i.e., MAP and behavioral incidents) was analyzed separately in relation to nature exposure indicators (i.e., tree canopy and permeable surface) across three different distances (i.e., $^{1}/_{10}$, ¼, or ½ mile from the school). These varying distances were examined in separate analyses to assess the sensitivity of their association with dependent variables. Table 5 provides the coefficients for each of these analyses, including beta coefficients for all analyses as well as incident rate ratios (IRR; i.e., the ratio of the incident rate among those exposed to an independent variable to the incident rate among those not exposed to an independent variable; Hilbe, 2007) for behavioral incident analyses.

These analyses detected few significant relationships among nature variables across these three examined distances. There was only one small main effect, which indicated that students in schools with more permeable surface within a half-mile performed slightly better on the MAP. Specifically, analyses indicated that, for every 10% increase in permeable surface within a half-mile radius of the school, students performed approximately 0.92 points better on the MAP assessment (which ranged from 112 to 279.5 in the study sample). In addition to this main effect, a trend that did not reach statistical significance ($p = 0.05$) was detected between behavioral incidents and half-mile nature indicators, such that students in schools with more permeable surface had fewer behavioral incidents. Because the half-mile nature indicators appeared to be most active or sensitive to association with the study's dependent variables, the half-mile nature indicators were used in subsequent analyses. Overall, model 1 results were somewhat mixed in their support for the hypotheses that higher levels of school nature exposure would be associated with better academic performance. Specifically, while tree canopy was not linked meaningfully with the academic indicators, findings yielded minimal support for the hypothesis that greater permeable surface would predict greater academic performance.

The models assessing differences in MAP scores explained approximately 98% of level-2 variance, most of which was explained by covariates including school type (i.e., middle or elementary), location within city limits, and proportion of students receiving FRL. This suggests that academic performance was primarily explained by the covariates and that there was little variance in MAP scores that could be explained by nature indicators from the school environment. In contrast, models assessing behavioral incidents explained less than half of the level-2 variance, and the model explaining the most level-2 variance (48%) used half-mile nature indicators.

3.2 Dose-Response of Nature Near Schools and Student Academic Functioning

To test the dose-response associations between nature near schools and student academic functioning, curvilinear trends for nature indicators were assessed. Table 6 provides beta coefficients for each of these analyses as well as IRRs for behavioral incident analyses. The only significant finding indicated that students' predicted odds of a behavioral incident increased in schools with greater tree canopy within half-mile distance from the school. This finding contradicted expectations, as it was anticipated that there would be fewer behavioral incidents in schools near more tree canopy. Both linear and curvilinear trends were significant, and the linear trend suggested that there was a strong tendency for students in schools with high levels of nearby tree canopy to have behavioral incidents. However, the magnitude of nature coefficients should be interpreted cautiously, as these are exaggerated because they depict differences in risk of behavioral incidents between students in schools with 100 percent tree canopy compared to students in schools with "zero" tree canopy, and neither of those tree canopy values are realistic possibilities in this context.

To facilitate interpretation of the curvilinear trend, IRRs based on linear and curvilinear trends were estimated (Table 7) and graphed (Figure 5) for behavioral incidents across a range of tree canopy exposure, including Very Low Canopy (i.e., *M* - 2 *SD*), Low Canopy (i.e., *M* - 1 *SD*), Average Canopy (i.e., *M*), High Canopy (i.e., *M* + 1 *SD*), and Very High Canopy (i.e., *M* + 2 *SD*). These estimates illustrate that the likelihood of a student having a behavioral incident was greatest in schools with High Canopy. Additionally, a ratio of IRR estimates for Very Low to Very High Canopy schools indicated that students in schools with Very High Canopy had approximately 30.7% greater odds of a behavioral incident than students in schools with Very Low Canopy. This model accounted for 48% of the variance attributable to the school-level, which was 3% greater than the linear model (model 1).

3.3 Nature Exposure Moderating Group Differences in Academic Functioning

To test for differential student responses associated with school nature, nature indicators were examined as moderators to the relationships between academic functioning and student or school characteristics. Table 8 provides the coefficients for each of these analyses, including beta coefficients for all analyses as well as IRRs for behavioral incident analyses.

Three analyses in the moderator model identified significant group differences regarding the association between tree canopy and academic functioning including (a) disproportionately lower academic performance among LEP students, (b) disproportionately more behavioral incidents among non-LEP students, and (c) disproportionately more behavioral incidents among Black students. Each of these significant findings will be discussed in turn.

3.3a Lower Academic Performance among LEP Compared to Non-LEP Students

Tree canopy was a significant predictor of an LEP to non-LEP academic performance gap, such that LEP students tended to perform worse on the MAP when there was more tree canopy. To facilitate interpretation, MAP scores were estimated for LEP and non-LEP students across a range of tree canopy exposure levels, including Low Canopy (i.e., *M* - 1 *SD*), Average Canopy (i.e., *M*), and High Canopy (i.e., *M* + 1 *SD*). These estimates were graphed (Figure 6) and demonstrate that LEP students' academic performance was disproportionately worse as school tree canopy levels increased. However, these differences were relatively small in an absolute sense, as LEP students performed approximately 1 point worse on the MAP in High Canopy compared to Low Canopy schools. In contrast, non-LEP students' academic performance was relatively stable across different levels of tree canopy. These results were inconsistent with expectations, as it was anticipated that non-LEP students would exhibit greater academic performance in schools with High Canopy compared to Low Canopy, and LEP students' academic functioning would remain relatively stable regardless of their exposure to tree canopy. Differential trends among LEP students in relation to academic performance and tree canopy accounted for little to no additional variance at the school or student level (98% of level-2 variance and 66% of level-1 variance) compared to the main effects model (model 1).

3.3b More Behavioral Incidents among Non-LEP Compared to LEP Students

Tree canopy was a significant predictor of the LEP to non-LEP behavioral incident gap, such that LEP students tended to have fewer behavioral incidents when there was more tree canopy. To facilitate interpretation, IRRs for both LEP and non-LEP students were estimated (Table 9) and graphed (Figure 7) to depict behavioral incident trends across a range of tree canopy exposure, including Low Canopy (i.e., *M* - 1 *SD*), Average Canopy (i.e., *M*), and High Canopy (i.e., *M* + 1 *SD*). IRR estimates illustrate that although there was little association between tree canopy and LEP students' probability of a behavioral incident, the odds of a non-LEP student having a behavioral incident was greatest in schools with High Canopy. Furthermore, a ratio of the odds of LEP to non-LEP students' behavioral incidents indicates that in schools with Average Canopy, the odds of a behavioral incident were 31.4% greater for non-LEP students compared to LEP students. These results were inconsistent with expectations, as it was anticipated that non-LEP students would have fewer behavioral incidents in schools with High Canopy compared to Low Canopy, and LEP students' behavioral incidents would remain relatively stable regardless of their exposure to tree canopy. Differential trends among LEP students in relation to behavioral incidents and tree canopy accounted for little to no additional variance at the school or student level (48% of level-2 variance and 31% of level-1 variance) compared to the main effects model (model 1).

3.3c More Behavioral Incidents among Black Compared to Non-Black Students

Tree canopy was a significant predictor of the Black to non-Black behavioral incident gap, such that Black students tended to have more behavioral incidents when there was more tree canopy. To facilitate interpretation, IRRs for both Black and non-Black students were estimated (Table 9) and graphed (Figure 8) to depict behavioral incident trends across a range of tree canopy exposure, including Low Canopy (i.e., *M* - 1 *SD*), Average Canopy (i.e., *M*), and High Canopy (i.e., *M* + 1 *SD*). IRRs illustrate that Black students were most likely to have a behavioral incident in schools with High Canopy; however, there was little association between tree canopy and non-Black students' probability of a behavioral incident. Furthermore, a ratio of the odds of Black to non-Black students' behavioral incidents indicates that in schools with Average Canopy, the odds of a behavioral incident were almost ten times greater for Black students compared to non-Black students. These results were inconsistent with expectations, as it was anticipated that Black students would have fewer behavioral incidents in schools with High Canopy compared to Low Canopy, and non-Black students' behavioral incidents would remain relatively stable regardless of their exposure to tree canopy. Differential trends among Black students in relation to behavioral incidents and tree canopy accounted for little to no additional variance at the school level (48% of level-2 variance) and accounted for 1% more variance at the student level (32% of level-1 variance) compared to the main effects model (model 1).

3.4 Summary of Results

In summary, the majority of results failed to reject the null hypothesis, and many of those in which the null hypothesis was rejected (i.e., significant associations were detected) contradict the anticipated direction such that worse academic functioning was associated with higher levels of nearby nature. Table 10 provides an overview of study research questions, hypotheses, and results.

CHAPTER 4: DISCUSSION

4.1 Overview of Study Aims, Hypotheses, Findings, and Factors Influencing Interpretation

This effort examined associations between Charlotte-Mecklenburg public school students' (K-8th grade) academic functioning (i.e., testing performance and behavioral incidents on record) and schools' level of nearby nature (i.e., tree canopy and permeable surface). Specifically, it was hypothesized that students in schools with greater nature exposure would perform better academically and have fewer behavioral incidents. Additionally, it was hypothesized that there may be a point at which additional nature exposure was associated with diminishing returns for academic benefits, or that there would be an optimal level of nature exposure associated with the greatest level of student academic functioning. Finally, it was hypothesized that students of demographic backgrounds that are more prone to adversity (i.e., low-SES, Black, and disability status) or tend to have worse outcomes associated with adversity (i.e., males, older, and non-immigrant) would benefit more from nature exposure than their counterparts.

The following subsections (a) summarize study results and the extent to which those were consistent with expectations, (b) describe additional research that may explain unexpected findings, and (c) convey aspects of the study's methods and design that impact interpretation and conclusions that can be drawn.

4.1a Summary of Study Results

The present analyses yielded few significant results, many of which contradicted the expected direction articulated in study hypotheses as well as findings from the extant literature. In brief overview, there was one direct association between nature and student performance indicators – students performed slightly better on the MAP (an aggregate of spring math and reading scores) in schools with greater permeable surface compared to students in schools with less permeable surface. Nature indicators that were assessed within a half-mile radius of the school were most active in their association with student outcomes; therefore, the remaining analyses examined higher order effects using half-mile nature indicators.

Results from analyses exploring the optimal dose of nature for student functioning yielded one significant finding – a student's probability of a reported behavioral incident was greatest in schools with High Canopy (*M* + 1 *SD*), whereas the odds were slightly lower in schools with Average Canopy (*M*) or Very High Canopy (*M* + 2 *SD*). The odds of a behavioral incident were lowest for students in schools near the least tree canopy.

Finally, moderation analyses revealed that there were group differences for both Black and LEP students – Black students' and non-LEP students' probability of a behavioral incident was greatest in high-canopy schools, and non-Black and LEP students' probability of a behavioral incident were relatively unrelated to tree canopy near schools. Additionally, while LEP students performed less well on academic testing in high-canopy schools compared to low-canopy schools, non-LEP students' academic performance was relatively unrelated to tree canopy near schools.

Thus, overall, many of the current study's findings were inconsistent with extant literature, and the observed direction of significant relationships contradicted expectations. In light of this set of findings, it is necessary to consider factors and conditions that may have contributed to potential negative responses to nature nearby schools as well as limitations that may have had a substantial impact on study analyses and results.

4.1b Possible Explanations for Negative Associations with Nearby Tree Canopy

Although additional research is necessary to understand the factors that contributed to the present study's unexpected findings, which may have been influenced by methodological limitations (cf. Section 4.1c), it is valuable to consider the potential risk of certain natural environments. Specifically, the paragraphs that follow outline the circumstances in which natural environments may contribute to stress responses associated with detrimental effects on well-being. It is also necessary to consider whether the half-mile proximity to natural elements examined in the current study captured students' possible exposure to natural elements in a manner that corresponds to the mechanisms thought to underlie the benefits of nature exposure. The half-mile indicators may also have implications for the quality or structure of natural landscapes (e.g., dense woodlands versus well-maintained street trees) that were assessed, which may have contributed to the current study's findings.

While the conclusions that can be drawn from the current study are limited, its results suggest that caution should be exercised when considering or explaining potential student behavioral benefits of nature near schools. This study's results also warrant caution when weighing the potential risks of nature-based interventions, which some have minimized or characterized as less serious compared to more invasive interventions (e.g., medical; Frumkin, 2013; Gill, 2014). That is, these results suggest that the risks of excessive nature exposure could be more substantial than once thought.

That said, the relevant research base is not well-developed, and further research is necessary to guide conclusions regarding the potential benefits and risks of nature-based programming and interventions. For instance, the present results regarding behavioral incidents are largely incongruent with those from the existing literature, which suggest that youth exhibit behavioral improvements in response to nature exposure (e.g., fewer ADHD symptoms, more prosocial behaviors, fewer conduct problems; Balseviciene et al., 2014; Faber Taylor & Kuo, 2009; Han, 2009; Markevych et al., 2014; Matsuoka, 2010; Scott et al., 2015; Wells, 2000). However, the studies in the extant literature have largely examined much more proximal nearby nature (e.g., in or around one's home), relatively groomed or well-maintained natural environments (e.g., parks), or active engagement in natural settings (e.g., after walking in the park). Many elements of the present study's emphasis reflect methodological distinctions from prior work – it focuses on passive exposure to nearby nature in the surrounding neighborhood, it does not account for the variability in the degree to which greenspaces have been maintained, and it does not permit examination of the degree to which students have had direct engagement with nearby nature. These differences might explain the fact that the present results conflict with those of many prior efforts.

The main findings from this study involved the prevalence of natural elements within a half-mile radius of each school, a distance that extends far beyond the schoolyard and could include residential lots, wooded areas, and commercial property. Because many schools have relatively tree-less schoolyards, a trend that has been observed across several U.S. cities (Schulman & Peters, 2008), the half-mile tree canopy indicator likely captured nearby woodland areas just outside the schoolyard. In fact, although the decision to use nature indicators within a half-mile radius of the school was guided by the present study's data, some sampled schools with the greatest proportions of half-mile tree canopy actually had very little tree canopy near the school itself (e.g., within a radius of one-tenth of a mile), yet proximity to dense woodlands contributed to a high level of tree canopy within a half-mile of the school.

The present study did not account for differences in tree canopy quality, which would have made a distinction between schools with large, mature and evenly-dispersed trees and schools with relatively barren landscapes except for dense, adjoining woodlands. To illustrate this point further, Figure 9 uses satellite images of sampled elementary schools to provide an example of four schools with similar proportions of tree canopy within a half-mile of the school, but clear variability in tree canopy quality (e.g., dense woodlands versus relatively dispersed canopy). Based on satellite imagery, it appears that many schools with high levels of half-mile tree canopy adjoin surrounding woodlands. Moreover, nearby woodlands may be relatively inaccessible and free from human influence, unmanaged, dense and overgrown, and dark or shadowy; there is some suggestion that such characteristics may induce, rather than reduce, stress responses (e.g., Maruthaveeran & van den Bosch, 2014; Shanahan et al., 2015).

The possibility that dense nearby woodlands contributed to the current study's findings has meaningful implications for the interpretation of study results. Of greatest salience, substantial proportions of students in the study may not have had access to greenspaces that would have allowed them to experience nature in the ways Kaplan and

Kaplan (1989) theorized would support mental restoration (e.g., immersion in a natural environment; engagement or fascination with aesthetically pleasing natural elements). If tree canopy is outside of the schoolyard (reducing opportunities for student engagement) and at a distance that reduces students' ability to see those trees from school windows, then there may be little likelihood that the trees are contributing to processes thought to underlie the benefits of nature exposure. Furthermore, if crowded woodlands are not perceived as aesthetic, then the possibility for immersion and fascination with natural elements may be limited. Overall, students may not have been exposed to tree canopy within a half-mile of the school in ways that would be expected to yield cognitive or behavioral benefits.

Theories emphasizing associations between nature and survival that induce stress-reduction and cognitive benefits (e.g., Ulrich, 1983) also hold relevance here, particularly because dense and overcrowded natural settings may trigger stress responses associated with survival (e.g., fear of predators). It may be that many students in high-canopy schools were exposed to dense, dark, and overcrowded woodlands. If such unkempt natural settings trigger an innate sense of risk (e.g., fear of predators; limited options for escape), then it would be expected that exposure to those environments would elicit a detrimental stress response and worse cognitive functioning. This notion that potentially detrimental responses may be associated with some forms of nature exposure aligns with Shanahan and colleague's (2015) hypothesis that crowded and complex vegetation could increase stress and contribute to poor health outcomes. In fact, some work suggests that congested or shadowy woodlands characterized by limited visibility may increase fear and diminish perceived safety (Jansson et al., 2013; Maruthaveeran & van den Bosch, 2014), which aligns with Ulrich's (1983) notion that natural environments trigger psycho-physiological responses based on individuals' survival instinct.

Heightened stress responses may depend on individual perceptions of the natural environment, a potentially important factor when framing the circumstances in which nature exposure may yield benefits (Hartig et al. 2014). For instance, people largely tend to prefer landscapes characterized by moderately dense vegetation with distinct natural elements, which create greater spatial definition. In turn, individuals more typically prefer balanced landscapes with built and natural elements, or landscapes that are relatively open with some distinct natural elements (e.g., trees; Kaplan & Kaplan, 1989). In contrast, individuals tend to report diminished preference for less defined landscapes including those that are extremely open (e.g., farm land) or very closed or blocked (e.g., dense vegetation; Jansson et al., 2013; Kaplan & Kaplan, 1989). These trends in individuals' preferences may reflect cognitive and instinctive processes because it is easier to extract information about safety in a moderately dense natural setting compared to those with blocked areas where it is difficult to anticipate what might happen. At either extreme, wide-open and undifferentiated natural settings as well as impenetrable woodlands, there is a lack of orderliness or information that conveys one's whereabouts or provides directional cues. Such orderliness and control in the natural environment may be particularly salient for individuals who have lives that are less "orderly" (p. 114), who likely desire a sense of clarity regarding at least one aspect of their lives (Kaplan & Kaplan, 1989). This possibility is corroborated by research that has found individuals who have previously experienced victimization tend to have a heightened sense of fear related to urban greenspaces (Maruthaveeran & van den Bosch, 2014).

Fear in relation to dense wooded areas constitutes a common theme in the literature around perceptions of natural settings, and appears to be impacted by structural qualities of the natural environment. For example, openness and clear sight lines likely diminish fear because physical and visual access allow one to move freely through the setting, enable more options for escape from possible danger, and reduce the potential for being surprised and unprepared to address threats to safety (Jansson et al., 2013; Kaplan & Kaplan, 1989; Maruthaveeran & van den Bosch, 2014). In fact, more than half of the studies that were part of a systematic review on perceived safety in relation to greenspaces reported that dense, unmaintained vegetation was a major factor contributing to fear of crime (Maruthaveeran & van den Bosch, 2014).

This fear may be induced by evolutionary intuition regarding the structure of the environment, but may also be influenced by signs of physical disorder (e.g., abandoned cars, graffiti, litter, property damage) that signal possible threat related to neighborhood crime (Maruthaveeran & van den Bosch, 2014). To this end, some studies have found that residents report that urban greenspaces have a reputation of being a "haven for antisocial activities" (Jansson et al., 2013, p. 131), such as criminal gangs, use or distribution of illegal drugs, or illegal dumping (Bogar & Beyer, 2015; Maruthaveeran & van den Bosch, 2014). Although studies in the U.S. show that fear of crime may be much more prevalent than actual victimization (Maruthaveeran & van den Bosch, 2014), at least one study has demonstrated that the presence of small, dense, and cluttered trees may be associated with increased crime rates (Donovan & Prestemon, 2012).

4.1c Interpreting Results Cautiously in the Context of Study Limitations

Although there is some empirical rationale regarding potentially adverse responses to dense and unmanaged vegetation that helps to explain study results, a number of study limitations warrant discussion prior to further consideration and interpretation of the present findings. Highlighting the potential relevance of such factors is particularly warranted because many of the current study's findings were inconsistent with those in the extant literature and the direction of relationships contradicted expectations. These considerations largely involve the inability to draw causal conclusions from study results due to its cross-sectional design and the possibility that explanatory variables at the neighborhood-level were not accounted for in analyses.

A noteworthy limitation is the present study's inability to account for neighborhood-level conditions that may explain both a greater presence of nature exposure and heightened student behavioral problems or school discipline practices. Of particular salience, the study did not account for indicators of neighborhood disadvantage that may have correlated with student misbehavior or harsher school discipline practices. Optimally, research would account for neighborhood-, school-, and student-level factors influencing student outcomes; however, a number of pragmatic and analytic considerations limited the ability of the current study to account for neighborhood-level conditions. For example, because multiple schools were part of the same neighborhood, the use of neighborhood indicators would have violated assumptions of independence in this 2-level study design. As such, the inclusion of neighborhood covariates would have either required excluding data from schools that were part of the same neighborhood or using a 3-level model; the latter option was not practical because the sample size and power at the neighborhood level would have been limited. This limitation eliminated the ability to account for aspects of neighborhood structural disadvantage, such as poverty and unemployment, violent crime, and other signs of physical disorder (e.g., abandoned or foreclosed homes), as well as indicators of neighborhood investment (e.g., extent to which others contribute to maintaining and improving the neighborhood) and development (e.g., new construction or renovation). Furthermore, dense woodlands that are not well-maintained may indicate relatively less neighborhood investment compared to neighborhoods with more planned green spaces (e.g. street trees). Conversely, more trees may indicate a lack of neighborhood development, which is corroborated by study findings indicating that new housing developments in Indiana were associated with less tree canopy (Heynen & Lindsey, 2003). Moreover, correlations from the current study indicate that tree canopy tends to be greatest in low-income schools, which suggests that neighborhood disadvantage may be conflated with heightened levels of tree canopy near schools.

It is problematic that the current study did not account for potential neighborhood confounds that reflect neighborhood structural disadvantage (e.g., neighborhood poverty, violent crime) because such disadvantage has been found to adversely impact academic achievement, behavior problems, perceived safety, and peer interactions and conflict (Maschi, Perez, & Tyson, 2010; McCoy, Roy, & Sirkman, 2013; Santiago & Galster, 2014). Additionally, victimization may be more likely in neighborhoods with physical disorder (e.g., exposure to violence; Santiago & Galster, 2014), and prior victimization (including exposure as a witness) would likely exacerbate a student’s fear of dark, intimidating woodlands (Jansson et al., 2013; Maruthaveeran & van den Bosch, 2014). Furthermore, the perceived lack of maintenance or of neighborhood investment (i.e., actions that maintain or improve neighborhood conditions) potentially associated with some urban greenspaces (e.g., neglected or overgrown) may signal to potential criminal offenders that an area is not managed or cared for, therefore increasing the prevalence of criminal behavior and disorder in the neighborhood (Maruthaveeran & van den Bosch, 2014).

The prevalence of crime is closely connected to the issue of neighborhood disorder and disadvantage, and some research has investigated whether crimes are more or less prevalent in relation to the presence of trees and greenspaces. Although the bulk of research to date suggests that crime, especially violent crime, is lower in communities with more greenspace, considerable variation in methods and measured outcomes have contributed to mixed findings (Bogar & Beyer, 2015). Similarly, the body of research on nature and academic or behavioral effects is fraught with methodological variability, and little research on either academic or criminal behavior has examined how differences in the quality of tree canopy may contribute to differential outcomes. A particularly noteworthy study found an association between dense and over-crowded trees near homes and greater property and nuisance crimes, whereas the presence of large, mature trees was associated with fewer violent crimes (Donovan & Prestemon, 2012). Authors theorized that large trees were associated with reduced crime because they were less view-obstructing than smaller and denser trees, whereas overcrowded groves of trees could obstruct views and mask potential perpetrators as well as indicate social disorganization in the neighborhood. Overall, the literature suggests that neighborhood crime may be a particularly salient omitted variable in the current study because crime may be conflated with diminished tree canopy quality, neighborhood disadvantage, and student misconduct.

Crime, low-income status, and neighborhood disorder may also relate to stricter school discipline practices (e.g., Arcia, 2007; Gregory et al., 2010; Irwin et al., 2013), which could have a bearing on the behavioral dependent variable in the current study. Behavioral incidents, a primary dependent variable here, are tracked and reported only after school personnel identify the transgression and initiate disciplinary action. Responses, including the recognition, reporting, and documentation of the behavioral incident, likely vary based on the discretion of school administrators and teachers (e.g., some schools may respond more consistently to transgressions such as oppositionality, bullying, or dress code violations). This discretionary response may lead to a greater propensity to document and reprimand perceived misbehavior in schools embedded in low-income and high-crime neighborhoods. Such schools are often staffed with less experienced personnel who may be more apt to engage in harsh discipline practices with the intent to strengthen school and student safety by punishing inappropriate behavior (Arcia, 2007). In fact, a nationally representative study found that students are punished with more exclusionary discipline practices (e.g., out-of-school suspension) in schools with higher levels of neighborhood crime (Irwin et al., 2013). Furthermore, neighborhood violence and crime may increase parents' fear, which may be used as a justification for harsher school discipline practices (Irwin et al., 2013). Because neighborhood disadvantage and school discipline practices were not addressed in the present study, particular caution is warranted when interpreting results related to reported behavioral incidents.

The following sections continue to build on these plausible explanations for study results when interpreting each set of findings related to guiding research questions, including (a) direct associations between nearby nature and student academic functioning, (b) optimal dose of nearby nature for academic functioning, and (c) group differences in the association between academic functioning and nearby nature. Following those sections, there is additional discussion of (d) study limitations, (e) study contributions, (f) potential implications and future directions, as well as (g) concluding remarks.

4.2 Direct Associations between Nearby Nature and Student Academic Functioning

There was one significant main effect, which indicated that students in schools with more permeable surface within a half-mile performed slightly better on academic testing compared to students in schools with less permeable surface. Although the association was small, the relationship was consistent with research demonstrating higher cognitive functioning in relation to nature exposure (e.g., Faber Taylor & Kuo, 2009). Nevertheless, the lack of relationships between nature and the study's academic indicators at all distances from the school was unexpected and contrasted with previous research (e.g., Matsuoka, 2010; Wu et al., 2014).

Results of model 1 (i.e., testing main effects of nature exposure in relation to academic functioning) were reviewed to identify at which distance nature indicators were most sensitively associated with students' academic functioning; this determined the distance examined in models testing higher order effects (i.e., model 2 testing curvilinear trends, model 3 testing moderators). Nature indicators that were assessed within a half-mile radius were more sensitive in these analyses than nature indicators assessed within a tenth-mile or quarter-mile radius. This result is comparable to findings from a study examining standardized test performance in relation to nature exposure assessed at three distances from the school (Wu et al., 2014). The authors of that work suggested that more distal measures may more accurately reflect exposure to greenspaces because nearby residential areas, in which students live, are likely captured (Wu et al., 2014). Because subsequent models for the study's key analyses used the most active and distal indicators for nature exposure, limited conclusions can be drawn regarding the potential benefit of natural elements in schoolyards. Instead, results apply more generally to the natural environments in the school's surrounding neighborhood.

Results of model 1(i.e., testing direct associations between nature and academic indicators) also demonstrated that the majority of the variance in academic performance (i.e., MAP scores) at the school-level was explained by covariates, which makes this indicator of academic functioning relatively insensitive to environmental predictors. Instead, the school-level variance in academic performance was largely explained by the type of school (i.e., with higher performance in middle schools), location within city limits (i.e., with lower performance in city schools), and proportion of students receiving FRL (i.e., with lower performance in more impoverished schools). It is likely that there was little school-level variance that could be predicted by nature exposure variables after accounting for these covariates, a circumstance that helps explain why there were so few findings related to nature indicators and academic performance.

Furthermore, the lack of main effect results coupled with the detection of several higher-order effects (i.e., curvilinear effects and moderators) suggest that direct relationships may be overly-simplistic as they did not best explain associations between academic functioning and nature exposure. In contrast, response to nature exposure may be better understood with regard to context, including differential responses based on dosage to natural elements (i.e., model 2), student characteristics (i.e., model 3), and quality of the natural environment (cf. Section 4.1b regarding perceptions and quality). The latter was not examined in this study and further limits our understanding of study results.

4.3 Behavioral Response Associated with Different Levels of Nearby Nature

With the intent of identifying a potential "optimal" dose of tree canopy, two analyses examined potential curvilinear trends for each dependent variable across levels of tree canopy and permeable surface within a half-mile of schools. There was one significant finding, which was inconsistent with expectations and results from the extant literature: students in schools with High Canopy had the greatest odds of a behavioral incident compared to students in schools with Average or Very High Canopy. The odds of a behavioral incident were lowest for students with the least amount of tree canopy. In contrast, no significant trends were detected for academic performance (i.e. MAP), which was inconsistent with the findings of a similar study that found standardized test performance was greater in relation to vegetation volume located within a 2000-meter distance from the school (Wu et al., 2014). The lack of findings in the present study may be attributable to the limited variance in MAP scores that could be explained by environmental factors. Alternatively, perhaps the detrimental behavioral trend associated with tree canopy (i.e., more behavioral incidents among children in schools with greater nearby tree canopy) offset the potential to detect benefits to academic functioning because behavior problems and academic achievement are highly and inversely interrelated (Fleming et al., 2004; McIntosh et al., 2008).

The present effort's findings regarding behavior suggest that a low level of tree canopy within a half-mile of the school is most optimal for student behavior. This association contradicts results from the extant literature that otherwise suggest that nature exposure near or in schools has the potential to positively influence child behavior (e.g., Han, 2009; Matsuoka, 2010; Martensson et al., 2009; Scott et al., 2015). No studies were found in the present review that demonstrated a potentially detrimental effect of nature exposure on student functioning. However, most previous studies have examined nature indicators that extended no further than the schoolyard.

One recent effort (Scott et al., 2015) is most comparable to the present work because it examined associations with tree canopy (in aggregate, across the neighborhood and beyond the school setting) in the same metropolitan school system as the current study. That study found that preschool students in schools near more trees improved more in behavior and emotional regulation, which contrasts sharply with the present study's results; however, that study used a younger (i.e., preschool) sample and a standardized, normative measure of behavior (i.e., not comparable to behavioral incidents in the present study), and controlled for home neighborhood nature exposure and aspects of neighborhood disadvantage (i.e., neighborhood poverty and violent crime). The latter distinctions may be most profound for explaining why the present study's results do not align with those from this prior effort. Neighborhood disadvantage may be greater in neighborhoods with more canopy, and violent crime may contribute to worse student behavior or increase documentation of student behavioral incidents. For instance, the present study examined reported behavioral incidents, which may be impacted by school discipline practices (cf. Section 4.1c for a review). In that vein, the present study may have found different results if the behavioral indicator was based on a standardized measurement tool rather than relying on reported behavior, which may be subject to the discretion of teachers and administrators.

Although the findings of the present study contradict what was expected, the results highlight the value and importance of measuring the potential influence of neighborhood characteristics and distant nature indicators on student functioning. This aligns with the notion that environmental and school conditions may play a substantial role in students' development (e.g., Kelz et al., 2013; Monsur, 2015). Moreover, because direct associations (i.e., linear models) were not detected until accounting for differential response based on tree canopy levels (i.e., curvilinear trend), the results also demonstrate the utility of examining differential associations with an outcome variable across different levels of nature exposure. These findings build on and extend prior research that had yet to demonstrate a curvilinear effect or dose-response trend in relation to the quantity of natural elements (e.g., Jiang et al., 2016; Shanahan et al., 2016; Wells & Evans, 2003). Results suggest that the natural environment surrounding the school, beyond the school yard, may impact student functioning. These findings suggest that future research investigating nature and behavior should account for or describe the context of the surrounding natural environment. Such efforts may help to contextualize potential null or unexpected findings, particularly with regard to small-scale nature interventions (e.g. occurring in schoolyards or classrooms).

In addition to examining more systematic indicators for behavior and accounting for potential confounds such as neighborhood disadvantage, results from the present study may have differed if other natural settings or features had been examined. For instance, this study only examined curvilinear trends associated with nature in the half-mile radius, which likely included dense, dark, nearby woodlands. The use of more proximal indicators would have been consistent with the methods used in a large majority of research (e.g., Han, 2009; Kelz et al., 2013; Matsuoka, 2010). Furthermore, results may have differed if more novel environments with short-term exposure had been investigated, such as studies examining the cognitive benefits after a walk in the park (e.g., Taylor Faber & Kuo, 2009). There are several reasons why benefits may be more likely in such circumstances, including that: behavioral responses tend to be strongest during an initial introduction period (whereas response diminishes when individuals habituate to a setting; Bringslimark, Hartig, & Patil, 2009; Shanahan et al., 2015), the novelty of a natural setting may increase awareness or appreciation of natural elements, and the intent of nature engagement may be apparent to study participants, increasing the likelihood they respond in expected ways (e.g., Hawthorne effect; Landsberger, 1958). In contrast, the current study examined academic achievement among students who had been exposed to the school environment for the entire school year or longer (e.g., for those who had attended the same school for multiple grades), and it is unlikely that students were prompted to attend to and appreciate the nearby natural setting. In this circumstance, woodlands near the school may represent a mundane aspect of the school environment that received relatively little attention from students.

A final consideration for interpreting the significant curvilinear trend indicating students in High Canopy schools were most likely to have a behavioral incident is the differential impact that was detected for Black students. Because Black students comprise about one-third of the study sample, the increased risk of behavioral incidents associated with tree canopy within a half-mile of the school may be partially explained by the disproportionate risk associated with tree canopy for Black students. Plausible explanations for racial differences associated with tree canopy are discussed in the next section.

4.4 Group Differences in the Association between Academic Functioning and Nearby Nature

The third set of analyses sought to examine the extent to which nature exposure might reduce disparities associated with certain groups or schools, or otherwise disproportionately benefit certain students. The hypotheses were based on the theory that nature exposure may disproportionately benefit students from groups that tend to experience greater adversity or stressors (e.g., students who attend impoverished schools, are Black, or have a disability) or tend to have poorer academic outcomes associated with adversity (e.g., students who are older, male, or from non-immigrant backgrounds). Study results did not support hypotheses and, in some cases, contradicted what was expected. In short, this study provides little support for the hypothesis that nature may buffer the effects of adversity; in fact, dense woodlands in the school neighborhood may present as a risk factor that exacerbates student disparities. This is counter to what was expected based on prior research demonstrating that children who experience adversity and life stressors tend to benefit most from nature exposure (Corraliza Collado & Bethelmy, 2012; Wells & Evans, 2003).

Because hypotheses were based on group-level trends for heightened adversity exposure and disparities in academic functioning (e.g., test performance, behavior), it is important to recognize that this study did not directly test the potential for nature to buffer the effects of adversity; therefore, this study cannot be conclusive about the extent to which vulnerable students are more or less apt to benefit from natural environments. Instead of assessing specific aspects of adversity (e.g., asking students directly about adverse childhood experiences), the study drew on archival data and relied on proxy variables that would indicate, on average, greater adversity based on group membership (e.g., students in poorer schools; minority students). This limits the comparability of the current study results to those of prior studies examining adversity more directly (e.g., Corraliza Collado & Bethelmy, 2012; Wells & Evans, 2003). While the findings pertaining to Black and LEP students may be noteworthy, the results must be interpreted cautiously because group characteristics are intended to serve as proxies for different experiences related to adversity. Caution is particularly warranted because socio-cultural factors outside of adversity may explain these results.

Specifically, perceptions and preferences related to natural environments may vary across socio-cultural or ethnoracial lines (Byrne & Wolch, 2009), which may have contributed to what appeared to be a detrimental response to nearby tree canopy within a half-mile of schools among certain groups of students (e.g., students who are Black). Such varying preferences and views may contribute to differences in perceived safety and utilization across localities as well as ethnoracial and sociodemographic groups. Most salient is that fear of urban greenspaces may be particularly pronounced among ethnic minorities (Maruthaveeran & van den Bosch, 2014). For example, research has documented that some ethnic minorities fear racism from other park users, and that fear decreases the use of public facilities among minorities (Elmendorf, Willits, & Sasidharan, 2005). To that end, greenspaces in neighborhoods with more ethnic minority residents may be more likely to be neglected or marred by criminal activity (e.g., Elmendorf et al 2005; Heynen & Lindsey, 2006; Jansson et al., 2013). Thus, experiences with racism or illicit activities near or in greenspaces may contribute to differential perceptions and utilization of greenspaces among ethnic minorities (Jansson et al., 2013; Maruthaveeran & van den Bosch, 2014). Additionally, some research has demonstrated that socialization patterns may explain greenspace utilization and leisure patterns across ethnic groups. For example, research exploring group differences in park utilization has suggested that Asian and Latino residents enjoy visiting parks with extended families, Black residents enjoy park spaces for organized recreational opportunities, and White residents enjoy secluded natural settings and individual activities (Byrne & Wolch, 2009).

In sum, it is expected that race-related perceptions and fear related to greenspaces may have contributed to differential outcomes in the present study. This notion is explored further in the following sections, which review the results in the context of additional literature to guide interpretation of group differences associated with nearby nature, including (a) behavioral incidents among non-LEP and Black students, (b) academic performance among LEP students, and (c) the lack of differential associations involving other groups of students.

4.4a Tree Canopy and Behavioral Incidents among Black and Non-LEP Students

Associations between tree canopy and behavioral incidents among Black and non-LEP students are discussed together here because the disproportionate risk among non-LEP students is likely explained by the large majority of Black students included in the non-LEP group. For both Black and non-LEP students, the probability of a behavioral incident in High Canopy schools was disproportionately greater than in Low Canopy schools; in contrast, the trends for non-Black and LEP students were relatively consistent across schools that varied in tree canopy level. The most pronounced trend indicated that Black students' probability of a behavioral incident was greatest in high-canopy schools. Although smaller in magnitude, the results for non-LEP students paralleled those for Black students. The inclusion of Black students in the non-LEP group, and the low number of Black students in the LEP group (i.e., 1.9% of Black students also had LEP status, reflecting 0.06% of the total sample), likely explains the heightened risk of behavioral incidents among non-LEP students in High Canopy schools. Moreover, the inclusion of non-Black students in the non-LEP group (i.e., 60% of non-LEP students were not Black) likely explains why the trends for the LEP-related differences were less pronounced than those detected for Black students. To consider what might be contributing to worse behavioral outcomes among Black students in High Canopy schools, two theories are explored below that could potentially explain these findings, aligning with the literature around perceptions of urban woodlands and school discipline practices (cf. Section 4.1).

Prior research has discovered marked distinctions between Black and White groups' perceptions and preferences for natural environments. Research suggests that Black individuals tend to prefer more neat, manicured, open, and structured settings marked by human influence, whereas White individuals tend to prefer natural settings with dense foliage and overgrown vegetation (Elmendorf et al., 2005; Kaplan & Kaplan, 1989). Additionally, there may be different patterns of utilization of natural spaces such as parks. Not only are Black individuals less likely than individuals of other ethnoracial backgrounds to be satisfied with parks in their neighborhood (Elmendorf et al 2005), they are also less likely to visit natural areas such as parks (Byrne & Wolch, 2009) or participate in outdoor activities as children (Elmendorf et al., 2005). Such exposure and early life experiences (e.g., access to play in woodlands) are associated with more positive attitudes and less fear of woodland vegetation (Jansson et al., 2013). Although it appears that Black students may adversely respond to woodlands near their schools, the extant literature suggests that Black individuals enjoy and appreciate nature, but may be rather selective about the natural environments in which they prefer to spend time.

In addition to marked preferences, on average, for planned greenspaces among Black individuals, access to organized and managed natural settings may vary across racial lines. That is, in neighborhoods that have a large Black population, greenspaces may be less orderly, increasing the propensity for perceived fear and a sense of neighborhood disorder. As one example, a study regarding tree canopy and residential perceptions in Milwaukee documented similar levels of tree canopy between neighborhoods with high proportions of Black or White residents; however, the quality varied dramatically as Black residents described the presence of unintended and unmaintained trees that cause nuisance and property damage (e.g., growing alongside foundations; Heynen & Lindsey, 2006). The potential for schools with more Black students to have dense and unmaintained tree canopy exacerbates the possible impact of a methodological flaw in the present study, as differences in tree canopy quality may help to explain racial differences in behavioral incidents.

Furthermore, the potential variability in quality of natural environments across racial lines may further qualify approaches to environmental justice. Disproportionate access to greenspace across minority groups has been framed as a social justice issue because a lack of access is a known correlate with worse health outcomes (e.g., Jennings, Johnson Gaither, & Gragg, 2012); however, this assumes a crude distinction between more and less greenspace, without respect to the quality of the surrounding nature. Among environmental justice advocates, there is a need for a more nuanced view of access to greenspace that considers the type or quality of greenspace. The present study's findings illustrate why caution should be taken when advocating for gross increases in greenspace without regard to the quality and maintenance of those spaces.

In addition to tree canopy quality, another potential confound not addressed in the present study is related to school discipline practices. A substantial body of research has demonstrated that Black students are often more frequently and severely disciplined than White students; the literature among Latino students is less consistent and robust, indicating that they may be less impacted by disparities in school discipline than Black students (Gregory et al., 2010). While the average SES of students in a school may contribute to the discipline gap between Black and non-Black students, SES does not fully explain the racial discipline gap (Gregory et al., 2010); therefore, the inclusion of FRL as a covariate in the current study was likely insufficient for accounting for differences in discipline practices. Additionally, the demographic composition of a school may contribute to variation in school-wide discipline practices. For instance, the proportion of Black students in a school is a known predictor of disciplinary outcomes; even White students are disciplined more harshly at schools with greater proportions of Black students (Skiba, Trachok, Chung, Baker, & Hughes, 2012). Alternatively, Black students may be at greater risk of harsher discipline practices compared to White students in relatively well-resourced schools (Gregory et al., 2010). Taken together, the extant research suggests that racial composition may impact school climate or discipline practices in ways that disproportionately impact Black students.

In addition to school-level factors that contribute to harsher discipline practices, on an individual-level, Black students may be more likely to be referred for behavior transgressions that involve the subjective judgments of school personnel (e.g., disrespect, excessive noise, defiance or noncompliance) compared to White students (Gregory et al., 2010). Furthermore, the subjective nature of discipline practices and harsher implications for Black students may coincide with neighborhood disorganization (e.g., poverty or violent crime, both of which may be correlated with tree canopy), leading to harsher discipline practices for Black students in disadvantaged neighborhood schools. This possibility is consistent with study findings revealing that neighborhood disadvantage (i.e., higher levels of crime and poverty) was associated with worse discipline outcomes (i.e., suspensions) among Black students (Williams, Davis, Saunders, & Williams, 2002). If tree canopy is greater in more disadvantaged neighborhoods, the omission of neighborhood indicators may explain group differences because harsher school discipline practices may be more prevalent in high canopy, disadvantaged schools. In sum, both diminished preferences for woodlands and the potential for neighborhood conditions to disproportionately affect Black youths' school discipline outcomes may explain greater levels of behavioral incidents among Black students in schools with greater nearby tree canopy.

4.4b Tree Canopy and Academic Performance among LEP Students

It was expected that non-LEP students would demonstrate better academic functioning in more natural school environments because students from immigrant families (using LEP-status as a proxy) tend to be less impacted by risk factors that are otherwise detrimental to academic achievement (Chun & Mobley, 2014; Degboe et al., 2012; Kolker, 2011). Study results contradicted this expectation, as LEP students' academic performance was slightly worse in high-canopy schools compared to low-canopy schools, and there was little association between academic performance and tree canopy for non-LEP students. This suggests that immigrant status may have contributed to disproportionate academic risk in relation to nearby woodlands.

This finding contradicts the immigrant advantage theory (i.e., tendency for immigrants to exhibit better well-being compared to native-born citizens despite risk factors such as poverty; Chun & Mobley, 2014; Degboe et al., 2012; Kolker, 2011) because it is expected that students of immigrant backgrounds would be less likely to be negatively impacted by adversity or risk (whereas tree canopy appears as a risk factor in this circumstance). However, in the broader literature, findings related to a possible immigrant advantage are mixed (Chun & Mobley, 2014), and the present study – perhaps because of its methodological limitations – may represent another investigation that contributes to inconsistencies in that research base (Teruya & Bazargan-Hejazi, 2013). Additionally, these results were surprising because LEP students' behavioral incidents did not follow a pattern similar to those for academic performance, as behavior problems and academic achievement are typically inversely related (Fleming et al., 2004; McIntosh et al., 2008).

Research around neighborhood conditions and immigrant student performance may help to contextualize these results. Of particular salience, neighborhood conditions for immigrant students tend to be less desirable than neighborhoods for native-born students (Pong & Hao, 2007). In addition to neighborhood disadvantage contributing to immigrant students' academic performance, the extent to which students live in ethnic enclaves may have a bearing on their academic performance. One study (Pong & Hao, 2007) that made notable and substantial contributions to the literature examined a nationally representative sample of immigrant and native-born students and found that adolescent immigrant students tend to have lower GPAs when they live in relatively impoverished neighborhoods that are home to many immigrant residents (see also Hibel & Hall, 2014).

In general, findings regarding immigrant students' academic achievement may be better understood by considering aspects of acculturation, or the extent to which a person maintains their connection and identification with a culture of origin (Kloos et al., 2012). More specifically, immigrant enclaves may create community conditions that enable separation from and a lack of assimilation with the language and values of the dominant culture (Kloos et al., 2012). A lack of opportunities for immigrant students living in ethnic enclaves to engage with the dominant language may be a barrier for academic achievement. Research evidence suggests that while such enclaves may be protective and facilitate some positive child outcomes (e.g., health; see Kim, Collins, & Grineski, 2014), living in such neighborhoods may also be associated with poorer academic performance (e.g., Hibel & Hall, 2014; Pong & Hao, 2007). Additional findings by Pong and Hao (2007) support this theory, as immigrant children who speak Spanish at home have lower GPAs, and their academic achievement may be relatively more influenced by community characteristics (e.g., school-SES) than family-level factors (e.g., individual-SES), whereas the reverse was true for native-born students (Pong & Hao, 2007). Together, although an individual's developmental level holds relevance, the research suggests that immigrant students who do not assimilate with the dominant language may be at an academic disadvantage.

While there is some evidence to suggest that immigrant students' academic achievement may be affected by insular ties to the culture of origin and limited exposure to the dominant culture (e.g., Pong & Hao, 2007), studies can address this tendency by accounting for the proportion of immigrants living in a neighborhood. This was not done in the current study; this reflects a methodological limitation because some of Charlotte's Hispanic enclave neighborhoods (e.g., east Charlotte) are very dense with tree canopy. Therefore, heightened levels of tree canopy in immigrant-dense neighborhoods may explain the tendency for LEP students in schools with greater tree canopy to perform worse on academic testing.

4.4c Considering Null Results

It is not clear why the other groups examined did not have differential academic outcomes associated with nature exposure, especially if dense tree canopy is associated with neighborhood disadvantage. Assumptions underlying hypotheses around nature as a buffer to the effects of adversity involved nearby nature inducing restoration and stress reduction; however, current study results suggest that this did not hold for students exposed to nearby wooded areas, and such exposure may have actually increased stress responses among certain groups. Therefore, groups experiencing disproportionate adversity, discrimination, and other stressors would not have responded more positively to nearby nature because stress reduction was likely not realized. As such, there appears to be no disproportionate benefit of nature exposure to students' academic functioning based on SES, disability status, gender, or age.

Although some of these null results are inconsistent with prior research, this area of investigation is not well-developed and there was little prior research on which to base other hypotheses. For instance, there was minimal research on which to base hypotheses related to age, and only one study was found that examined disproportionate benefit based on disability status. Results were inconsistent with that study, which suggested that students with emotional and behavioral challenges improved most among children attending a forest school (Roe & Aspinall, 2011). The present study may have revealed different results had disability statuses related to cognitive, emotional, and behavioral challenges been assessed more specifically.

Also counter to prior research were the null results pertaining to SES (i.e., school-level FRL). Research investigating adult health and child behavior in relation to neighborhood greenspace has demonstrated that individuals of lower-SES backgrounds tend to experience greater benefits associated with nature exposure than their higher-SES counterparts (e.g., Balseviciene et al., 2014; Mitchell & Popham, 2008). The present study's null results associated with SES were more consistent with a study investigating academic performance in relation to vegetation near schools, which also found no disproportionate benefit to students of low-SES (Wu et al., 2014). It could be that the

FRL data were not precise enough to reveal such differences, particularly because individual-level FRL data were not available from the school system for the current effort.

Lastly, null results pertaining to gender were inconsistent with the bulk of research suggesting that males tend to benefit more from nature exposure than females (e.g., Markevych et al., 2014; Richardson & Mitchell, 2010; Schutte et al., 2015). In contrast, the current study's results were more consistent with a study investigating academic performance in relation to vegetation near schools, which also found no disproportionate benefit to students of either gender (Wu et al., 2014). Null results in the current study regarding gender are surprising in the context of prior research suggesting that females may be particularly prone to fear in relation to dense, dark woodlands (Jansson et al., 2013; Maruthaveeran & van den Bosch, 2014). That research on perceptions and fear may not generalize to children. In contrast, regardless of gender, children may respond similarly in terms of their level of preference or perceived safety in relation to dense forested areas.

4.5 Limitations of the Current Study

While this study has some clear assets in its focus and design, its limitations underscore the need for judicious interpretation of its results, possible conclusions, and implications. Critically, the present study is unable to inform causal conclusions regarding the impact of tree canopy or permeable surface near the school on student academic functioning. Overall, because study results are not conclusive about the potential benefit of nature near schools, and these findings largely contradict those from the existing literature (e.g., Han, 2009; Markevych et al., 2014; Matsuoka, 2010; Scott et al., 2015), school decision-makers should be particularly cautious about drawing conclusions on this basis of this work.

A number of limitations to the current study have been discussed thus far, including those related to omitted variables (e.g., neighborhood conditions), a constraint that may explain the study's results. Because such omissions may also contribute to potential spurious correlations between natural environments and academic functioning, these correlational data must not be over-interpreted as meaningful (Vigen, 2015). Additionally, this study is cross-sectional and, in turn, study findings provide no indication of potential changes to student functioning in response to being introduced to a natural environment. That is, rather than conveying the extent to which natural elements contribute to differences in student functioning, study findings indicate associations between academic achievement and natural elements within a half mile of public schools in Charlotte, North Carolina.

A number of potential confounding variables were not examined in the present study, including neighborhood disorganization (e.g., poverty, crime), proportion of immigrants living in the neighborhood, and school discipline practices. Additionally, the study did not measure a number of factors and conditions that would be expected to underlie beneficial experiences to nature exposure. Mediators in the theory of change (Figure 1) such as stress response, cognitive functioning, and socio-emotional competencies were not assessed and may have helped to explain at what point nature exposure was not associated with anticipated processes thought to contribute to well-being.

Furthermore, several conditions that are not captured in the theoretical model might clarify study results, including how quality of nature exposure might precede the positive perceptions that are expected to facilitate the types of experiences necessary for stress reduction and cognitive restoration (e.g., Kaplan, 1995). The current study did not measure quality of tree canopy or perceived restoration, which could have revealed under what circumstances wooded areas may contribute to positive or negative student outcomes. Finally, the current study did not assess the extent to which students interacted with nearby nature. School proximity to greenspaces does not guarantee that students have connected with nearby nature in ways that would be expected to facilitate benefits (Hartig et al., 2014). In this sense, the notion of "exposure" in this study may not reflect actual conditions or experiences because it is uncertain the extent to which students were exposed to natural environmental features in meaningful ways. In a similar vein, study findings may differ based on the indicators used to assess nearby nature; for example, results may have been different if the visibility of trees from school windows were assessed. It is important to continue to identify strategies for how to operationalize "exposure to" or "engagement with" nature and to draw on multiple indicators of nature; doing so will enhance understanding of the sensitivity of particular indicators and the relationships of nature exposure and children's functioning.

Multiple study measures reflect another salient limitation, as several of the indicators used to assess student characteristics or outcomes, drawn from the school system's archival data, were mere proxies for indicators that aligned with the theory of change. For example, students' behavior was indicated by behavioral incidents that were reported and recorded by school staff and administrators. The variability with which behavioral incidents are identified or tracked limits what can be said about the relationship between nearby tree canopy and actual student behavior. Similarly, a different academic indicator than the MAP may have produced different results. Additionally, indicators for SES were limited because there were no indicators available to assess student-level SES, thus limiting analyses to school-level measures of SES. Further, the FRL variable may proxy SES, but is a very coarse indicator based on the self-report of parents applying for an assistance program. It also likely does not capture parents and students who choose not to pursue or do not know how to navigate the FRL application process (e.g., may disproportionately exclude undocumented immigrants), and may include students who would not truly qualify for the program if parent-reported income was verified. This limitation may have contributed to the heightened relationship between FRL and school racial composition, which precluded controlling for the percent of Black students at the school (a known predictor of discipline practices; Skiba et al., 2012) in the present work. Other proxy variables were used to examine the potential benefits of nature to groups of students who tend to experience heightened levels of adversity. Those demographic variables do not precisely measure stressful experiences such as the extent to which a child has experienced and perceived discrimination (e.g., Schmitt et al., 2014). Furthermore, LEP status was used to proxy immigrant backgrounds, and does not capture students with immigrant backgrounds who are fluent in English. Moreover, immigrant students are not homogenous, as there may be different trends among, across and within immigrant groups, or based on the age at which one immigrated to the United States. These limitations further contribute to the methodological concerns that limit the conclusions drawn about the immigrant paradox

(Teruya & Bazargan-Hejazi, 2013). In sum, more thorough and precise measurement tools may have yielded different study findings.

The study was further limited by analytic flaws that may have contributed to its complex set of findings. For instance, the extent to which students are exposed to natural settings in their home environment, which has been shown to have unique effects associated with student outcomes beyond those explained by school nature exposure (e.g., Scott et al., 2015), may have contributed to unexplained variance or error in current analytic models. However, the inclusion of home environment as a covariate could potentially exacerbate another challenge facing this study – shared variance among neighborhoods that are in close proximity to one another. Neighborhoods are interdependent with one another because what happens in one neighborhood is associated with what happens in other nearby neighborhoods (i.e., spillover effects; Morenoff, Sampson, & Raudenbush, 2001; Sampson, Morenoff, & Gannon-Rowley, 2002). In the present study, school-level nature indicators may be particularly correlated with one another because there were some schools in the sample for which half-mile boundaries overlapped, and this could have over-estimated the effects associated with nature indicators. Techniques (such as geographically weighted regression) to address this limitation were beyond the scope of the present study (e.g., Brunsdon, Fotheringham, & Charlton, 1996).

The study is further limited because the study sample is not generalizable to the CMS student body or school systems outside CMS. The sample excluded roughly one-third of the student population, including many students who were most vulnerable academically (e.g., students who were frequently truant or chronically absent, or had moved during the school year), and underrepresented Black students because they were more likely to be missing MAP data and to attend non-traditional schools or programs excluded from this study. Similarly, White students were overrepresented in the current study (cf. Section 2.1). The study is not generalizable to school systems outside CMS for multiple reasons, including that the average CMS student's academic performance is superior to that in most other urban school districts (e.g., CMS, n.d.-b.) and the City of Charlotte has a high level of tree canopy compared to other cities (e.g., Israel, 2016; Stabley, 2013). In other urban areas, there may be little possibility of detrimentally high levels of vegetation because more pronounced spatial constraints (e.g., population density) limit the potential for excessive nature exposure (Shanahan et al., 2015). Further illustrating the atypical characteristics of Charlotte and CMS schools are the correlations from the current study that indicate tree canopy is greatest in low-income schools. This tendency contradicts trends described in the professional literature (e.g., Kirkpatrick, Davidson, & Daniels, 2007; Shanahan et al. 2015) and in local news outlets (i.e., in Charlotte; Israel, 2016) because tree cover is typically greatest in more advantaged neighborhoods. It is possible that Charlotte's rapid growth may create temporary conditions that contributed to the study's unexpected findings, which may change meaningfully over time after major transitions conclude and neighborhoods become more stable. The generalizability of study results are also limited to urban students, as natural environments and behavioral response may differ for students in rural areas (Richard & Mitchell, 2010). Additionally, perceptions of fear in relation to vegetation may also vary by context – because prior research has shown that residential settings with well-maintained trees or shrubs are perceived as safer than residential areas with fewer natural elements (Maruthaveeran & van den Bosch, 2014), it may also be the case that findings may differ for studies examining greenspaces in residential versus school settings. Moreover, results are not generalizable to adults, and race-related effects may be more profound among children (who tend to experience greater psychological distress in response to racism) than adults (e.g., Schmitt et al., 2014).

4.6 Study Contributions

This study sought to build on the research base by examining urban nature near schools. The assumption underlying the exploration of academic and behavioral benefits associated with nearby nature was that interaction or direct contact may not be essential to realizing benefits of nature exposure in key environments for children. This distinction may help explain why some findings were incongruent with the extant literature, as most prior research has examined active or engaged forms of nature exposure (e.g., a walk in the park; Faber Taylor & Kuo, 2009) or passive nature exposure that is much more proximally located (e.g., in classrooms or schoolyards; Han, 2009; Matsuoka, 2010).

Notwithstanding the study's limitations and its unexpected findings, the results highlight the potential importance of environmental conditions, including distal nature indicators, to student functioning. Furthermore, these unexpected findings contribute to diversifying the literature base on nature exposure because, based on the current review, the potential risks of excessive nature exposure had not previously been demonstrated (e.g., Shanahan et al., 2016). This study contributes to the limited literature base regarding a potential optimal dose of nature exposure, and regarding potential differences in benefit (or detriment) associated with nature exposure across ethnoracial groups. In sum, despite its mixed or inconclusive findings regarding the impact of nature exposure on student functioning, the current study contributes to an underdeveloped literature base by exploring relationships that had previously received little attention.

Although the study is flawed largely because it does not account for potential omitted variables (e.g., nature quality, neighborhood conditions, school discipline practices), it does evidence several noteworthy methodological strengths. The sample size was adequate for detecting small effects at student and school levels, and multilevel modeling enabled the exploration of these effects by accounting for both student- and school-level variance without violating the assumption of independence. Much of the extant literature does not fully account for both individual and environmental differences, as studies often either aggregate data across individuals within a group setting (e.g., schools, Matsuoku, 2010; neighborhoods, Richardson & Mitchell, 2010) or examine outcomes between controlled groups based on absolute distinctions between natural and less natural conditions (e.g., Han, 2009; Faber Taylor & Kuo, 2009). The current study's analytic approach was further strengthened by the use of a negative binomial model for the behavioral incident models. This enabled the examination of the full range and variability across student discipline records, as opposed to transforming behavioral data into a dichotomous variable (i.e., students with zero or students with one or more behavioral incident). In sum, the analytic approach was able to disentangle associations between student and school levels and examine a more complete range of nearby nature and associated behavioral outcomes.

Notwithstanding the limitations of needing to use proxy and distal indicators, another clear methodological strength of the current study was the use of GIS to precisely and objectively measure nearby nature (i.e., tree canopy and permeable surface). This technique can be applied to population-level studies, as it is a relatively efficient mechanism for data collection compared to on-site observations of greenspace. However, the potential utility of this tool could be limited by the availability of precise land coverage data. The collection of the current study's land coverage data was contracted by Charlotte-Mecklenburg, and may be a relatively unique community asset. In fact, these data were considered to be particularly precise and accurate because of the methodological strength of the data collection process, which assessed land coverage with 1-meter resolution aerial images (O'Neil-Dunne, 2014). In contrast, the National Land Cover Database uses a spatial resolution of 30 meters (Homer et al., 2015), which is much less precise and would be unable to detect small trees. Charlotte-Mecklenburg land coverage data and the use of GIS allowed the current study to avoid the common pitfall of studies that use crude or imprecise measurements, and allowed the exploration of dose-response associations by examining a range of natural environments (Shanahan et al., 2015).

4.7 Potential Implications and Future Directions

In light of the current study's limitations, which point to the need to exercise caution when interpreting its findings, additional research is necessary before proceeding with action steps informed by work in this area. Nevertheless, there are a few possible applications that merit discussion; these are largely based on tentative explanations for study results derived from the extant literature. Because it is uncertain the extent to which trends revealed in prior research might explain the present findings, further research is needed prior to addressing prospective issues that may or may not explain the detrimental associations between student behavior and nearby tree canopy.

As an initial step, the data from the present study could be further analyzed to assess differential associations with dense versus even distributions of tree canopy, and to rule out potential confounding neighborhood-level variables that may explain study results. For instance, if poorer behavioral outcomes associated with tree canopy are explained by neighborhood disadvantage, then efforts to improve woodland quality may likely be futile for improving student outcomes. In addition to needed further research prior to implementing changes, improvement strategies should be piloted and complemented with rigorous evaluation methods to better ascertain their potential utility, which would also build on the limited research base regarding child functioning in relation to nature exposure.

It is clear that additional investigation is needed prior to and during the implementation of change strategies pertaining to structural woodland properties and student engagement with nearby greenspaces. For instance, while the extant literature suggests that student fear may be evoked by dense, obscure wooded areas, implying that woodland structural change may reduce student fear and distress, additional research regarding students' perceptions of nearby woodlands should guide prospective change efforts. For example, focus groups could be held with students in CMS schools with dense nearby canopy to understand their perceptions of those natural landscapes. If students indicate fear in relation to low visibility created by crowded and inaccessible greenspaces, this may justify structural changes to nearby woodlands because an open and maintained landscape would be expected to enhance perceived safety. Woodland spaces can be planned, designed, and managed to improve perceived safety by clearing dense vegetation, reducing ground cover, and removing low hanging branches and vegetation that block visibility, all of which ultimately raise tree canopies while preserving the natural landscape (Jansson et al., 2013; Maruthaveeran & van den Bosch, 2014). Alternatively, students may prefer increased presence of personnel who can monitor potential threats, which would be consistent with solutions suggested by residents in other related research (Jansson et al., 2013). This divergent example emphasizes the need to obtain further information about the underlying mechanisms that contributed to the current study's results before proceeding with action steps to amend potential detriment of dense, dark woodlands.

An additional strategy informed by prior findings that could be explored relates to the extent to which students are engaged with nearby greenspaces. Efforts to enhance student nature engagement might be coupled with efforts to improve the accessibility to those spaces through structural changes and regular maintenance. Prior research has demonstrated that familiarity and prior experiences with woodlands or denser, unadulterated natural environments are associated with less fear (Jansson et al. 2013; Maruthaveeran & van den Bosch, 2014). Building on the notion that more can be learned from students, focus groups could be employed to inquire about students' prior and desired experiences with nature, map their connections and access with nearby woodlands, and determine their preferences for engaging in natural environments. Because engagement in unkempt natural environments tends to be preferred by White individuals and ill-favored by Black individuals (Elmendorf et al., 2005), substantial input from students of color is critical for informing culturally competent responses that avoid coercing assimilation (e.g., encouraging conformity) with dominant group lifestyle preferences, norms, values, and attitudes. Alternatively, input and involvement from students of color may help to locally address historical “recreational racism” (p. 313), including disproportionate access to safe parks and urban forests (Elmendorf et al., 2005). Not only would such input have the potential to highlight possible inequities in greenspace quality or access, this could initiate student and family engagement in efforts that enable Black communities to recoup nearby urban greenspaces, promoting environmental justice through the inclusion in the use and enjoyment of urban forests (Jennings et al., 2012). Moreover, efforts to engage students of all ethnoracial backgrounds in natural environments should be evaluated to understand the potential for such approaches to address fear and promote positive academic outcomes.

In addition to investigating strategies to reduce student fear and enhance engagement with nearby woodlands, there are a number of ways to strengthen future research. Generally, there is a need for longitudinal research that investigates changes in relation to nature-focused interventions (Hartig et al., 2014). The two prospective interventions described above (i.e., creating an open forest structure; increasing student engagement with nearby woodlands) are more pragmatic for such research designs relative to interventions that aim to increase the presence of mature vegetation and trees, as the latter would either require a lengthy time period for vegetation to mature or inordinate costs associated with the installation of large, mature trees. This logistical barrier is likely the reason why much prior intervention research has investigated small-scale strategies to enhance vegetation (e.g., Han, 2009; Kelz et al., 2013). Yet, the current study demonstrates that those studies may be limited if they do not account for surrounding natural environments that may impact student functioning. Future research on small-scale natural interventions should account for or describe the context of the natural environment. Another practical longitudinal design that could be employed in future research would examine changes in behavior among students randomly selected to attend schools through the school options lottery (e.g., magnet schools). The random selection of students and placement into schools would minimize selection issues (such that students are not more prone to attend schools with more versus less nature exposure, regardless of student or family preferences for greenspace), strengthening the exploration of changes in student functioning associated with school nature.

The current study's limitations also point to a number of variables that should be accounted for when investigating nearby nature, including neighborhood disorder (e.g., poverty, crime) and greenspace quality (e.g., coding aerial images, Figure 9). Examining both neighborhood- and school-level effects, in addition to those related to the student-level, necessitates a different analytic strategy or hierarchical structure than the one employed in the present study. Future research adjusting for neighborhood conditions could use a three-level model (i.e., schools are nested within neighborhoods, and students are nested within schools; e.g., Skiba et al., 2012) or a class-classified model (i.e., in which students are nested within two level-2 groups – home neighborhoods and schools; e.g., Pong & Hao, 2007).

There is a pronounced need for future research examining nearby nature to account for the quality and type of greenspaces, such as tree height, crown size, number of trees in an area, low hanging branches, stem density, and variation in species, or the presence of overgrown groundcover (e.g., Conway & Bourne, 2013; Donovan & Prestemon, 2012; Jansson et al., 2013). Prior studies have demonstrated that aspects of tree quality are associated with different neighborhood conditions (Conway & Bourne,

2013) and different crime patterns (Donvan & Prestemon, 2012); therefore, aspects of tree quality may explain variation in behavioral responses. Collecting those data may require intensive resources for staff time (e.g., site visits and observations) or access to advanced data systems (e.g., Blue Sky, n.d.); therefore, future research might also explore less resource-intensive data collection strategies. For instance, because a mixture of built and natural features may be most preferred (Kaplan & Kaplan, 1989), future research could examine the interaction between impervious surface and tree canopy to assess the extent to which mixed-use environments (i.e., including built and natural elements) are most optimal for student functioning. Additionally, satellite images of tree canopy could be coded to indicate the presence of dense woodlands or relatively dispersed residential tree canopy (e.g., Figure 9).

4.8 Conclusion

Additional research regarding the potential benefit of nearby nature to students and children is needed. This study sought to contribute to knowledge in this area and build on prior research by investigating student academic functioning in relation to tree canopy and permeable surface near public schools in Charlotte, North Carolina. The results are inconclusive and suggest that heightened levels of permeable surface are slightly associated with better academic performance, yet high levels of tree canopy may be associated with poorer behavioral outcomes, particularly among Black students, as well as slightly poorer testing performance among immigrant students. These results may be explained by research that suggests members of Black communities often perceive dense, cluttered woodlands negatively (e.g., Maruthaveeran & van den Bosch, 2014). Additionally, several omitted variables might correlate with both greater amounts of tree canopy and poorer academic functioning, including neighborhood disorder (e.g., crime, poverty; e.g., Santiago & Galster, 2014), school discipline practices (e.g., Gregory et al., 2010), and the proportion of immigrants living in a neighborhood (e.g., Pong & Hao, 2007). Future efforts should prioritize exploring the extent to which neighborhood conditions are conflated with the quality of natural environments, students' perceptions of natural spaces, and student outcomes. Moreover, additional information elucidating why certain populations are disproportionately impacted by environmental conditions can aid a targeted approach to advancing environmental justice (e.g., Jennings et al., 2012) across ethnoracial groups.

REFERENCES

Akpinar, A. (2016). How is high school greenness related to students' restoration and health?. *Urban Forestry & Urban Greening, 16*, 1-8. doi: 10.1016/j.ufug.2016.01.007

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, *106*, 20-29. doi:10.1016/j.jecp.2009.11.003

Arcia, E. (2007). Variability in schools' suspension rates of Black students. *The Journal of Negro Education*, 76, 597-608.

Arnold, D. H., Kupersmidt, J. B., Voegler-Lee, M. E., & Marshall, N. (2011). The association between preschool children's social functioning and their emergent academic skills. *Early Child Research Quarterly, 27,* 376-386. doi:10.1016/j.ecresq.2011.12.009

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., & Nieuwenhuijsen, M. J. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *International Journal of Environmental Research and Public Health, 11,* 6757-6770. doi: 10.3390/ijerph110706757

Bagot, K. L., Allen, F. C. L., & Toukhsati, S. (2015). Perceived restorativeness of children's school playground environments: Nature, playground features and play period experiences. *Journal of Environmental Psychology*, *41*, 1-9. doi: 10.1016/j.jenvp.2014.11.005

Benfield, J. A., Rainbolt, G. N., Bell, P. A., & Donovan, G. H. (2015). Classrooms with nature views: Evidence of differing student perceptions and behaviors. *Environment and Behavior*, *47*, 140-157. doi: 10.1177/0013916513499583

Blue Sky (n.d.). *Tree mapping – From tiny acorns.* Retrieved on January 10, 2017 from http://www.bluesky-world.com/national-tree-map

Bogar, S., & Beyer, K. M. (2016). Green space, violence, and crime: A systematic review. *Trauma, Violence, & Abuse, 17*, 160-171. doi: 10.1177/1524838015576412

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, *29*, 422-433. doi: 10.1016/j.jenvp.2009.05.001

Brunsdon, C., Fotheringham, S., & Charlton, M. E. (1996). Geographically weighted regression: A method for exploring spatial nonstationarity. *Geographical Analysis, 28,* 281-298.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Cambridge, MA: Harvard University Press.

Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In W. R. Damon & R.M. Lerner (Series Eds.) & R.M. Lerner (Vol. Ed.), *Handbook of child psychology: Vol. 1, Theoretical models of human development* (6th ed., pp. 793–828). Hoboken, NJ: Wiley.

Byrne, J., & Wolch, J. (2009). Nature, race, and parks: Past research and future directions for geographic research. *Progress in Human Geography, 33*, 743-765. doi: 10.1177/0309132509103156

Charlotte Mecklenburg Schools. (n.d.-a). *Advanced studies and talent development*. Retrieved on September 19, 2016 from http://www.cms.k12.nc.us/cmsdepartments/ci/astd/Pages/Gateway.aspx

Charlotte Mecklenburg Schools. (n.d.-b). *Did you know?* Retrieved on September 19, 2016 from http://www.cms.k12.nc.us/mediaroom/aboutus/Pages/Didyouknow.aspx

Charlotte Mecklenburg Schools. (n.d.-c). *Exceptional children*. Retrieved on September 19, 2016 from http://www.cms.k12.nc.us/cmsdepartments/EC/Pages/default.aspx

Charlotte Mecklenburg Schools. (n.d.-d). *Global studies.* Retrieved on September 19, 2016 from http://schools.cms.k12.nc.us/mglaMGDHS/Pages/Global-Studies.aspx

Charlotte Mecklenburg Schools. (2016). *English language learner (ELL) services.* Charlotte, NC: Charlotte Mecklenburg Schools. Retrieved on August 25, 2016 from http://www.cms.k12.nc.us/cmsdepartments/ci/els/SiteAssets/ELS_Fact%20Sheet_2016.pdf#search=limited%20english%20proficiency

Chen, C. (2014). *Impact of nature window view on high school students stress recovery* (Master's thesis). University of Illinois at Urbana-Champaign. Retrieved from Illinois Digital Environment for Access to Learning and Scholarship at http://hdl.handle.net/2142/72897

Chun, H., & Mobley, M. (2014). The "immigrant paradox" phenomenon: Assessing problem behaviors and risk factors among immigrant and native adolescents. *Journal of Primary Prevention, 35*, 339-356. doi: 10.1007/s10935-014-0359-y

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, M., & Khalaila, R. (2014). Saliva pH as a biomarker of exam stress and a predictor of exam performance. *Journal of Psychosomatic Research*, *77*, 420-425. doi: 10.1016/j.jpsychores.2014.07.003

Conway, T. M., & Bourne, K. S. (2013). A comparison of neighborhood characteristics related to canopy cover, stem density and species richness in an urban forest. *Landscape and Urban Planning*, *113*, 10-18. doi: 10.1016/j.landurbplan.2013.01.005

Corraliza, J., Collado, S., & Bethelmy, L. (2012). Nature as a moderator of stress in urban children. *Social and Behavioral Sciences*, *38,* 253-263. doi: 10.1016/j.sbspro.2012.03.347

Daly, J., Burchett, M., & Torpy, F. (2010). Plants in the classroom can improve student performance. *National Interior Plantscape Association*.

Degboe, A., BeLue, R., & Hillemeier, M. (2012). Parental immigrant status and adolescent mental health in the United States: Do racial/ethnic differences exist?. *Child and Adolescent Mental Health*, *17*, 209-215. doi: 10.1111/j.1475-3588.2011.00636.x

Donovan, G. H. & Prestemon, J. P. (2012). The effect of trees on crime in Portland, Oregon. *Environment and Behavior*, *44*, 3-30.

Dzhambov, A. M., & Dimitrova, D. D. (2014). Elderly visitors of an urban park, health anxiety and individual awareness of nature experiences. *Urban Forestry & Urban Greening*, *13*, 806-813. doi: 10.1016/j.ufug.2014.05.006

Eisenberg, N., Sadovsky, A., Spinrad, T. L., Fabes, R. A., Losoya, S. H., Valiente, C., ... & Shepard, S. A. (2005). The relations of problem behavior status to children's negative emotionality, effortful control, and impulsivity: Concurrent relations and prediction of change. *Developmental Psychology, 41*, 193. doi: 10.1037/0012-1649.41.1.193

Elmendorf, W. F., Willits, F. K., & Sasidharan, V. (2005). Urban park and forest participation and landscape preference: A review of the relevant literature. *Journal of Arboriculture*, *31*, 311-317.

Faber Taylor, A. & Kuo, F. E. (2006). Is contact with nature important for healthy child development? State of the evidence. In C. Spencer & M. Blades (Eds.). *Children and their environments: Learning, using, and designing spaces* (pp. 124-140). Cambridge, UK: Cambridge University Press.

Faber Taylor, A. & Kuo, F. E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders, 12,* 402-409. doi: 10.1177/1087054708323000

Fleming, C. B., Harachi, T. W., Cortes, R. C., Abbott, R. D., & Catalano, R. F. (2004). Level and change in reading scores and attention problems during elementary school as predictors of problem behavior in middle school. *Journal of Emotional and Behavioral Disorders*, *12,* 130-144. doi: 10.1177/10634266040120030101

Friedman, H. S. (Ed.). (2011). *The Oxford handbook of health psychology*. New York, NY: Oxford University Press.

Frumkin, H. (2013). The evidence of nature and the nature of evidence. *American Journal of Preventive Medicine, 44,* 196-197. doi: 10.1016/j.amepre.2012.10.016

Garcia Coll, C. G., Lamberty, G., Jenkins, R., McAdoo, H. P., Crnic, K., Wasik, B. H., & Garcia, H. V. (1996). An integrative model for the study of developmental competencies in minority children. *Child Development. 67*, 1891-1914.

Gill, T. (2014). The benefits of children's engagement with nature: A systematic literature review. *Children Youth and Environments*, *24*, 10-34. doi: 10.7721/chilyoutenvi.24.2.0010

Graziano, P. A., Reavis, R. D., Keane, S. P., & Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology, 45,* 3-19. doi:10.1016/j.jsp.2006.09.002

Gregory, A., Skiba, R. J., & Noguera, P. A. (2010). The achievement gap and the discipline gap: Two sides of the same coin? *Educational Researcher*, *39*, 59-68. doi: 10.3102/0013189X09357621

Gunnar, M., & Quevedo, K. (2007). The neurobiology of stress and development. *Annual Review of Psychology*, *58*, 145-173. doi: 10.1146/annurev.psych.58.110405.085605

Han, K. (2009). Influence of limited visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior*, *41,* 658-692. doi: 10.1177/0013916508314476

Hartig, T., Mitchell, R., De Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, *35*, 207-228. doi: 10.1146/annurev-publhealth-032013-182443

Hasselhorn, M., Andresen, S., Becker, B., Betz, T., Leuzinger-Bohleber, M., & Schmid, J. (2015). Children at risk of poor educational outcomes: In search of a transdisciplinary theoretical framework. *Child Indicators Research, 8,* 425-438. doi: 10.1007/s12187-014-9263-5

Hatch, S. L., & Dohrenwend, B. P. (2007). Distribution of traumatic and other stressful life events by race/ethnicity, gender, SES and age: A review of the research. *American Journal of Community Psychology*, *40*, 313-332. doi: 10.1007/s10464-007-9134-z

Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment (2004). *Nature and health. The influence of nature on social, psychological and physical well-being*. The Hague, Netherlands: Health Council of the Netherlands and RMNO. Retrieved on August 28, 2016 from https://www.gezondheidsraad.nl/en/task-and-procedure/areas-of-activity/environmental-health/nature-and-health-the-influence-of-nature

Helms, A. D. (2014, June 7). CMS racial data refuels diversity concerns. *The Charlotte Observer.* Retrieved on August 25, 2016 from http://www.charlotteobserver.com/news/local/education/article9129296.html

Heynen, N. C., & Lindsey, G. (2003). Correlates of urban forest canopy cover implications for local public works. *Public Works Management & Policy*, *8*, 33-47. doi: 10.1177/1087724X03008001004

Hibel, J., & Hall, M. (2014). Neighborhood coethnic immigrant concentrations and Mexican American children’s early academic trajectories. *Population Research and Policy Review*, *33*, 365-391. doi: 10.1007/s11113-013-9314-5

Hilbe, J. M. (2007). *Negative binomial regression*. Cambridge, UK: Cambridge University Press.

Holzel, B. K., Lazar, S. W., Schuman-Oliver, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science, 6,* 537-559 doi: 10.1177/1745691611419671

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G… & Megown, K., (2015). Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing*, *81*, 345-354.

Howell, A. J., Dopko, R. L., Passmore, H. A., & Buro, K. (2011). Nature connectedness: Associations with well-being and mindfulness. *Personality and Individual Differences*, *51*, 166-171. doi:10.1016/j.paid.2011.03.037

Irwin, K., Davidson, J., & Hall-Sanchez, A. (2013). The race to punish in American schools: Class and race predictors of punitive school-crime control. *Critical Criminology*, *21*, 47-71. doi: 10.1007/s10612-012-9171-2

Israel, M. (March, 2016). *A city of trees, but for how long?* Retrieved on September 19, 2016 from http://keepingwatch.org/programming/air-trees/facing-threats-citys-beloved-trees-find-cadre-of-support

Janoff-Bulman, R. (1992). *Shattered assumptions.* New York: Free Press.

Jansson, M., Fors, H., Lindgren, T., & Wiström, B. (2013). Perceived personal safety in relation to urban woodland vegetation–A review. *Urban Forestry & Urban Greening*, *12*, 127-133. doi: 10.1016/j.ufug.2013.01.005

Jennings, V., Johnson Gaither, C., & Gragg, R. S. (2012). Promoting environmental justice through urban green space access: A synopsis. *Environmental Justice*, *5*, 1-7. doi: 10.1089/env.2011.0007

Jiang, B., Li, D., Larsen, L., & Sullivan, W. C. (2016). A dose-response curve describing the relationship between urban tree cover density and self-reported stress recovery. *Environment and Behavior*, *48*, 607-629. doi: 10.1177/0013916514552321

Jones, S. C., & Neblett, E. W. (2016). Future directions in research on racism-related stress and racial-ethnic protective factors for Black youth. *Journal of Clinical Child & Adolescent Psychology*. Advanced Online Publication. doi: 10.1080/15374416.2016.1146991

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice, 10*, 144-156. doi: 10.1093/clipsy/bpg016

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. New York, NY: Cambridge University Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169-182.

Kelz, C., Evans, G. W., & Röderer, K. (2013). The restorative effects of redesigning the schoolyard: A multi-methodological, quasi-experimental study in rural Austrian middle schools. *Environment and Behavior*. Advance online publication, 1-21. doi: 10.1177/0013916513510528

Kilmer, R. P. & Gil-Rivas, V. (2010). Exploring posttraumatic growth in children impacted by Hurricane Katrina: Correlates of the phenomenon and developmental considerations. *Child Development*, *81,* 1211-1227. doi: 10.1111/j.1467-8624.2010.01463.x

Kim, Y. A., Collins, T. W., & Grineski, S. E. (2014). Neighborhood context and the Hispanic health paradox: Differential effects of immigrant density on children′ s wheezing by poverty, nativity and medical history. *Health & Place*, *27*, 1-8. doi: 10.1016/j.healthplace.2014.01.006

Kirkpatrick, J. B., Davison, A., & Daniels, G. D. (2012). Resident attitudes towards trees influence the planting and removal of different types of trees in eastern Australian cities. *Landscape and Urban Planning*, *107*, 147-158. doi: 10.1016/j.landurbplan.2012.05.015

Kloos, B., Hill, J., Thomas, E., Wandersman, A., & Elias, M. J. (2012). *Community psychology: Linking individuals and communities*. Belmont, CA: Cengage Learning.

Kolker, C. (2011). *The immigrant advantage: What we can learn from newcomers to America about health, happiness and hope*. New York, NY: Simon and Schuster.

Landsberger, H. A. (1958). *Hawthorne revisited*. Ithaca, NY: Cornell University.

Leadbeater, B. J., Kuperminc, G. P., Blatt, S. J., & Hertzog, C. (1999). A multivariate model of gender differences in adolescents' internalizing and externalizing problems. *Developmental Psychology*, *35*, 1268-1282.

Levy, D. J., Heissel, J. A., Richeson, J. A., & Adam, E. K. (2016). Psychological and biological responses to race-based social stress as pathways to disparities in educational outcomes. *American Psychologist*, *71*, 455-473. doi: 10.1037/a0040322

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning*, *148*, 149-158. doi: 10.1016/j.landurbplan.2015.12.015

Lin, Y. H., Tsai, C. C., Sullivan, W. C., Chang, P. J., & Chang, C. Y. (2014). Does awareness effect the restorative function and perception of street trees? *Frontiers in Psychology*, *5*, 1-9.

Lindahl, M., Theorell, T., & Lindblad, F. (2005). Test performance and self-esteem in relation to experienced stress in Swedish sixth and ninth graders—saliva cortisol levels and psychological reactions to demands. *Acta Paediatrica*, *94*, 489-495. doi: 10.1080/08035250410025131

Lottrup, L., Stigsdotter, U. K., Meilby, H., & Claudi, A. G. (2015). The workplace window view: A determinant of office workers' work ability and job satisfaction. *Landscape Research*, *40*, 57-75. doi: 10.1080/01426397.2013.829806

Lovell, R., O'Brien, L., & Owen, R. (2010). *Review of the research evidence in relation to the role of trees and woods in formal education and learning.* Bristol, England: The Research Agency of the Forestry Commission. Retrieved on August 29, 2016 from http://www.forestry.gov.uk/website/pdf.nsf/pdf/education_and_learning_research_review_2010.pdf/$file/education_and_learning_research_review_2010.pdf

Luke, D. A. (2004). *Multilevel modeling* (Vol. 143). Thousand Oaks, CA: Sage.

Luthar, S. S. (1999). *Children in poverty: Risk and protective factors in adjustment*. Thousand Oaks, CA: Sage.

Maldonado, E. F., Fernandez, F. J., Trianes, M. V., Wesnes, K., Petrini, O., Zangara, A., ... & Ambrosetti, L. (2008). Cognitive performance and morning levels of salivary cortisol and [alpha]-amylase in children reporting high vs. low daily stress perception. *The Spanish Journal of Psychology*, *11*, 3-15. doi: 10.1017/S1138741600004066

Markevych, I., Tiesler, C. M., Fuertes, E., Romanos, M., Dadvand, P., Nieuwenhuijsen, M. J., ... & Heinrich, J. (2014). Access to urban green spaces and behavioural problems in children: Results from the GINIplus and LISAplus studies. *Environment International*, *71*, 29-35. doi: 10.1177/0013916508319745

Mårtensson, F., Boldemann, C., Söderström, M., Blennow, M., Englund, J.-E., & Grahn, P. (2009). Outdoor environmental assessment of attention promoting settings for preschool children. *Health & Place*, *15*, 1149–1157. doi:10.1016/j.healthplace.2009.07.002

Maruthaveeran, S., & van den Bosch, C. C. K. (2014). A socio-ecological exploration of fear of crime in urban green spaces–A systematic review. *Urban Forestry & Urban Greening*, *13*, 1-18. doi: 10.1016/j.ufug.2013.11.006

Maschi, T., Perez, R. M., & Tyson, E. (2010). Exploring the relationship between exposure to violence, perceptions of neighborhood safety, and children's adaptive functioning: Clinical and community implications. *Journal of Human Behavior in the Social Environment*, *20*, 744-761. doi: 10.1016/j.landurbplan.2012.05.015

Matsuoka, R. H. (2010). Student performance and high school landscapes. *Landscape* *and Urban Planning, 97,* 273-282. doi:10.1016/j.landurbplan.2010.06.011

Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2008). Why is nature beneficial? The role of connectedness to nature. *Environment and Behavior, 41,* 607-643. doi: 10.1177/0013916508319745

McCoy, D. C., Roy, A. L., & Sirkman, G. M. (2013). Neighborhood crime and school climate as predictors of elementary school academic quality: A cross-lagged panel analysis. *American Journal of Community Psychology, 52,* 128-140. doi: 10.1007/s10464-013-9583-5

McIntosh, K., Flannery, K. B., Sugai, G., Braun, D., & Cochrane, K. (2008). Relationships between academics and problem behavior in the transition from middle school to high school. *Journal of Positive Behavior Interventions, 10,* 243-255. doi: 10.1177/1098300708318961

Mitchell, R., & Popham, F. (2008) Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet, 372,* 1655-1660. doi: 10.1016/S0140-6736(08)61689-X

Mirrahimi, S., Tawil, N. M., Abdullah, N. A. G., Surat, M., & Usman, I. M. S. (2011). Developing conducive sustainable outdoor learning: the impact of natural environment on learning, social and emotional intelligence. *Procedia Engineering, 20,* 389-396. doi: 10.1016/j.proeng.2011.11.181

Monsur, M. (2015). *Does childcare architecture matter? Investigating how indoor-outdoor spatial relations influence child engagement and teacher motivation* (Doctoral dissertation). Retrieved from ProQuest (3690334).

Morenoff, J. D., Sampson, R. J., & Raudenbush, S. W. (2001). Neighborhood inequality, collective efficacy, and the spatial dynamics of urban violence. *Criminology, 39,* 517-560.

National Center for Educational Statistics. (n.d.). *Search for public school districts*. Retrieved on September 19, 2016 from http://nces.ed.gov/ccd/districtsearch/district_detail.asp?ID2=3702970

North Carolina Department of Public Instruction (2014). *Understanding North Carolina's annual measurable objectives*. Retrieved on April 6, 2017 from http://www.ncpublicschools.org/docs/accountability/reporting/amotargets.pdf

Northwest Evaluation Association (2011). *Technical manual for Measures of Academic Progress (MAP) for primary grades (MPG).* Portland, OR: Northwest Evaluation Association.

Northwest Evaluation Association (2016). *Linking the North Carolina EOG assessments to NWEA MAP tests.* Retrieved on September 19, 2016 from https://www.nwea.org/content/uploads/2016/03/North_Carolina_Linking_Study_MAR2016.pdf

O'Neil-Dunne, J. (2014). *A report on existing and possible tree canopy in the city of Charlotte and Mecklenburg County, NC.* Burlington, VT: Spatial Analysis Laboratory at the University of Vermont. Retrieved from http://treescharlotte.org/wp-content/uploads/2014/02/TreeCanopy_Report_MecklenburgCountyNC.pdf

Ozer, E. J. (2007). The effects of school gardens on students and schools: Conceptualization and considerations for maximizing healthy development. *Health Education & Behavior*, *34,* 846-863. doi: 10.1177/1090198106289002

Paddle, E., & Gilliland, J. (2016). Orange is the new green: Exploring the restorative capacity of seasonal foliage in schoolyard trees. *International Journal of Environmental Research and Public Health*, *13*, 497. doi: 10.3390/ijerph13050497

Pachter, L.M., & Garcia Coll, C. (2009). Racism and child health: A review of the literature and future directions. *Journal of Developmental Behavioral Pediatrics*, *30*, 255-263. doi: 10.1097/DBP.0b013e3181a7ed5a

Peek, M. K., Cutchin, M. P., Salinas, J. J., Sheffield, K. M., Eschbach, K., Stowe, R. P., & Goodwin, J. S. (2010). Allostatic load among non-Hispanic Whites, non-Hispanic Blacks, and people of Mexican origin: Effects of ethnicity, nativity, and acculturation. *American Journal of Public Health*, *100*, 940-946. doi:10.2105/AJPH.2007.129312.

Pretty, J. (2004). How nature contributes to mental and physical health. *Spirituality and Health International*, *5*, 68-78. doi: 10.1002/shi.220

Pong, S. L., & Hao, L. (2007). Neighborhood and school factors in the school performance of immigrants' children. *International Migration Review*, *41*, 206-241. doi: 10.1111/j.1747-7379.2007.00062.x

Raudenbush S. W., Bryk A. S., Cheong Y. F., Congdon R. T., & du Toit, M. (2011). *HLM 7: Hierarchical linear and nonlinear modeling.* Chicago, IL: Scientific Software International.

Reiss, F. (2013). Socioeconomic inequalities and mental health problems in children and adolescents: A systematic review. *Social Science & Medicine*, *90*, 24-31. doi: 10.1016/j.socscimed.2013.04.026

Roe, J. & Aspinall, P. (2011). The restorative outcomes of forest school and conventional school in young people with good and poor behavior. *Urban Forestry & Urban Green, 10*, 205–212. doi:10.1016/j.ufug.2011.03.003

Roe, J., Aspinall, P. A., Marvos, P., & Coyne, R. (2013). Engaging the brain: The impact of natural versus urban scenes using novel EEG methods in an experimental setting. *Environmental Sciences, 1*, 93-104. doi: 10.12988/es.2013.3109

Russell, R., Guerry, A. D., Balvanera, P., Gould, R. K., Basurto, X., Chan, K. M., ... & Tam, J. (2013). Humans and nature: How knowing and experiencing nature affect well-being. *Annual Review of Environment and Resources*, *38*, 473-502. doi: 10.1146/annurev-environ-012312-110838

Sampson, R. J., Morenoff, J. D., & Gannon-Rowley, T. (2002). Assessing "neighborhood effects": Social processes and new directions in research. *Annual Review of Sociology, 28*, 443-478.

Santiago, A. M., & Galster, G. C. (2014). The effects of childhood exposure to neighborhood and community violence: Impacts on the safety and well-being of low-income, minority children. *Journal of Community Practice*, *22*, 29-46. doi: 10.1080/10705422.2014.901271

Savage, A., McConnell, D., Emerson, E., & Llewellyn, G. (2014). Disability-based inequity in youth subjective well-being: Current findings and future directions. *Disability & Society*, *29*, 877-892. doi: 10.1080/09687599.2014.880331

Schmitt, M. T., Branscombe, N. R., Postmes, T., & Garcia, A. (2014). The consequences of perceived discrimination for psychological well-being: A meta-analytic review. *Psychological Bulletin*, *140*, 921-948. doi: 10.1037/a0035754

Schulman, A., & Peters, C. A. (2008). GIS analysis of urban schoolyard landcover in three US cities. *Urban Ecosystems*, *11*, 65-80. doi: 10.1007/s11252-007-0037-4

Schutte, A. R., Torquati, J. C., & Beattie, H. L. (2015). Impact of urban nature on executive functioning in early and middle childhood. *Environment and Behavior*. Advance online publication. doi: 10.1177/0013916515603095

Scott, J. T., Kilmer, R. P., Wang, C., Cook, J. R., & Haber, M. G. (2015). *Natural environments in home and school neighborhoods: Potential benefits for socio-emotional development in early childhood.* Manuscript in preparation.

Shanahan, D. F., Fuller, R. A., Bush, R. Lin, B. B. & Gaston, K. J. (2015). The health benefits of urban nature: How much do we need? *BioScience*, *65*, 476-485. doi:10.1093/biosci/biv032

Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Dean, J., Barber, E., & Fuller, R. A. (2016). Health benefits from nature experiences depend on dose. *Scientific Reports*, *6*, 1-10. doi: 10.1038/srep28551

Skiba, R. J., Trachok, M., Chung, C. G., Baker, T., & Hughes, R. (2012, April). *Parsing disciplinary disproportionality: Contributions of behavior, student, and school characteristics to suspension and expulsion.* Paper presented at the Annual Meeting of the American Educational Research Association, Vancouver, British Columbia, Canada.

Slade, M., Lowery, C., & Bland, K. (2013). Evaluating the impact of forest schools: A collaboration between a university and a primary school. *Support for Learning*, *28*, 66-72.

Stabley, S. (2013, February 18). Charlotte earns tree award. *Charlotte Business Journal.* Retrieved on August 25, 2016 from http://www.bizjournals.com/charlotte/print-edition/2013/02/08/charlotte-earns-tree-award.html

Teruya, S. A., & Bazargan-Hejazi, S. (2013). The immigrant and Hispanic paradoxes: A systematic review of their predictions and effects. *Hispanic Journal of Behavioral Sciences*, *35*, 486-509. doi:10.1177/0739986313499004.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. W., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*, 201-230. doi:10.1016/S0272-4944(05)80184-7

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Human behavior and the environment* (Vol. 6., pp. 85-125). New York, NY: Plenum Press.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*, 420-421. doi: 10.1126/science.6143402

Ursache, A., Blair, C., & Raver, C. C. (2012). The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure. *Child Development Perspectives, 6*, 122-128. doi: 10.1111/j.1750-8606.2011.00209.x

Vigen, T. (2015). *Spurious correlations.* New York, NY: Hachette Books.

Visu-Petra, L., Cheie, L., Benga, O., & Miclea, M. (2011). Cognitive control goes to school: The impact of executive functions on academic performance. *Procedia-*

Social and Behavioral Sciences, 11, 240-244. doi: 10.1016/j.sbspro.2011.01.069

Vitasari, P., Wahab, M. N. A., Herawan, T., Sinnadurai, S. K., Othman, A., & Awang, M. G. (2011). Assessing of physiological arousal and cognitive anxiety toward academic performance: The application of catastrophe model. *Procedia-Social and Behavioral Sciences, 30*, 615-619. doi: 10.1016/j.sbspro.2011.10.119

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape & Urban Planning, 105,* 221–229. doi:10.1016/j.landurbplan.2011.12.015

Wells, N. M. (2000). At home with nature: Effect of "greenness" on children's cognitive functioning. *Environment and Behavior*, *32*, 775-793. doi:10.1177/00139160021972793

Wells, N. M., & Evans, G. W. (2003). Nearby nature: A buffer of life stress among rural children. *Environment and Behavior*, *35*, 311-330. doi:10.1177/0013916503035003001

White, R. (2004). *Interaction with nature during the middle years: Its importance in children's development and nature's future*. Kansas City, MO: White Hutchinson Leisure & Learning Group. Retrieved August 29, 2016 from https://www.whitehutchinson.com/children/articles/nature.shtml.

Williams, T. R., Davis, L. E., Saunders, J., & Williams, J. H. (2002). Friends, family, and neighborhood: Understanding academic outcomes of African American youth. *Urban Education*, *37*, 408-431.

Williams, D. R., Priest, N., & Anderson, N. B. (2016). Understanding associations among race, socioeconomic status, and health: Patterns and prospects. *Health Psychology*, *35*, 407-411. doi: 10.1037/hea0000242

Wu, C. D., McNeely, E., Cedeno-Laurent, J. G., Pan, W. C., Adamkiewicz, G., Dominici, F., ... & Spengler, J. D. (2014). Linking student performance in Massachusetts elementary schools with the “greenness” of school surroundings using remote sensing. *PloS One*, *9*, e108548. doi:10.1371/journal.pone.0108548

Table 1: Descriptive Statistics for Key Study Variables

Variable	*n* (%)	*M*	*SD*	*Range*
Student-Level Characteristics+				
Age (years)	-	8.79	2.59	4-15
Male	33,772 (50.9%)	-	-	-
Race and Ethnicity				
African American	22,280 (33.6%)	-	-	-
American Indian	282 (0.4%)	-	-	-
Asian	3,966 (6%)	-	-	-
Hispanic	14,051 (21.2%)	-	-	-
Multi-Racial	1,556 (2.3%)	-	-	-
White	24,184 (36.5%)	-	-	-
LEP	11,658 (17.6%)	-	-	-
Exceptional Child Status	5,935 (8.9%)	-	-	-
AIG	5,918 (8.9%)	-	-	-
MAP RIT	-	202.48	27.22	112-279.5
Behavioral Incidents	-	0.26	1.26	0-49
Absences (% days)	-	0.04%	0.04%	0-0.67%
School-Level Characteristics				
City Limits	57 (62%)	-	-	-
Middle School	20 (21.7%)	-	-	-
% School Nature†	-			
Tree Canopy, 1/10 Mi	-	25.43%	12.09%	0-53.83%
Tree Canopy, ¼ Mi	-	45.56%	11.38%	22.17-80.71%
Tree Canopy, ½ Mi	-	48.91%	10.66%	25.14-80.8%
Permeable Surf., 1/10 Mi	-	59.03%	9.36%	34.63-91.94%
Permeable Surf., ¼ Mi	-	75.04%	7.8%	51.33-92.45%
Permeable Surf., ½ Mi	-	76.46%	8.4%	53.78-95.96%
% FRL	-	54.46%	29.56%	4.1-93.6%
Students Enrolled	-	825.33	246.4	411-1658

Note: + Student-Level Characteristics reflect categorical data tracked by the school system; LEP = Limited English Proficiency; AIG = Academic and Intellectually Gifted; MAP RIT = Measures of Academic Progress Rausch Unit scores (test scores);
† % School Nature indicates the proportion of nature variables within a specified distance of each school; Mi = mile; Permeable Surf. = permeable surface; FRL = Free and Reduced Lunch.

Table 2: Intercorrelations Among Study Variables at Level 1

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. MAP	.03**	.79**	-.15**	.34**	-.04**	-.14**	-.16**	-.12**	-.13**	-.21**	-.13**	-.07**	-.22**	-.01**	.03**
2. Behavioral Incidents		.09**	.1**	-.06**	.1**	.16**	-.05**	-.04**	.07**	-.01	.01**	.01*	-.02**	-.01	-.02**
3. Age			.06**	.13**	.01*	< .01	-.06**	.02**	-.02**	-.25**	-.1**	-.05**	-.29**	< .01	.02**
4. EC				-.1**	.09**	.05**	-.01**	< .01	.06**	.02**	.02**	.02**	.03**	.02**	.01**
5. AIG					-.01**	-.18**	-.13**	-.11**	-.07**	-.01**	-.04**	-.01**	-.02**	-.02**	-.01**
6. Male						< .01	< .01	.01**	< .01	-.01	< .01	< .01	.01	< .01	< .01
7. Black							-.37**	-.29**	.02**	< .01	.07**	.02**	-.03**	.04**	.03**
8. Hispanic								.62**	.03**	.09**	.11**	.07**	.09**	.03**	-.01**
9. LEP									-.02**	.07**	.1**	.07**	.05**	.03**	-.02**
10. % Days absent										.04**	.05**	.04**	.01**	.03**	.03**
11. Tree Canopy 1/10 Mile from School											.61**	.44**	.57**	.09**	-.05**
12. Tree Canopy ¼ Mile from School												.79**	.34**	.54**	.29**
13. Tree Canopy ½ Mile from School													.23**	.54**	.61**
14. Permeable Surface 1/10 Mile from School														.33**	.12**
15. Permeable Surface ¼ Mile from School															.76**
16. Permeable Surface ½ Mile from school															

Note: n = 66,319; * $p < 0.05$, ** $p < 0.01$; MAP = Measures of Academic Progress (average of spring math and reading scores); EC = disability status via Exceptional Child programs; AIG = Academic and Intellectually Gifted; LEP = Limited English Proficiency.

Table 3: Intercorrelations Among Study Variables at Level 2

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Tree Canopy 1/10 Mile from School	.56**	.41**	.52**	-.05	.07	-.27**	< .01	-.35**	.35**	-.28**	.14	-.03	.14	.12
2. Tree Canopy ¼ Mile from School		.78**	.28**	.29**	.54**	-.16	.09	-.23*	.27**	-.12	.31**	.15	.27**	.19
3. Tree Canopy ½ Mile from School			.2	.62**	.55**	-.09	.03	-.19	.07	-.08	.2	.03	.19	.17
4. Permeable Surface 1/10 Mile from School				.14	.33**	-.3**	-.14	-.44**	.09	-.34**	.01	-.17	.11	.26*
5. Permeable Surface ¼ Mile from School					.77**	.04	-.13	-.05	-.32**	.01	.02	.05	-.06	.15
6. Permeable Surface ½ Mile from School						.02	-.04	-.13	-.17	.01	.09	.08	.05	.22*
7. MAP							.07	.61**	-.26*	.87**	-.45**	-.31**	-.27**	-.05
8. Behavioral Incidents								.05	.23*	.18	.45**	.46**	.27**	.33**
9. Number of students enrolled									-.21*	.58**	-.26*	-.19	-.06	-.3**
10. In city limits										-.08	.38**	.35**	.29**	.02
11. Middle School											-.04	< .01	.09	-.05
12. % FRL students												.78**	.74**	.19
13. % Black students													.23*	.23*
14. % LEP students														.02
15. % EC students														

Note: $n = 92$; * $p < 0.05$, ** $p < 0.01$; MAP = Measures of Academic Progress (average of spring math and reading scores); FRL = Free and Reduced Lunch; LEP = Limited English Proficiency; EC = disability status via Exceptional Child programs.

Table 4: Null Model for Assessing Relationships between Student Academic Functioning and School Environment

	MAP	Behavioral Incidents
τ_{00}	231.16	1.54
σ^2	470.24	4.24
ICC	0.33	0.27

Note. MAP = Measures of Academic Progress (average of spring math and reading scores); Level-2 n = 92; τ_{00} = variance in Level-2 residual (i.e., unexplained variance between students in different schools); σ^2 = variance in Level-1 residual (i.e., unexplained variance among students in the same school); ICC = Intraclass Correlation Coefficient.

Table 5: Direct Associations between Student Academic Functioning and Nature Indicators at Three Distances

Variable	MAP Scores		
	1/10 Mile	¼ Mile	½ Mile
Level 2			
Intercept	212.89**	212.81**	212.54**
Elementary School	-13.48**	-13.54**	-13.54**
City Limits	-1.0*	-0.84†	-0.41
# Students Enrolled	< 0.01	< 0.01	< 0.01
% FRL	-0.11**	-0.11**	-0.11**
% Tree Canopy	< 0.01	-0.22	-2.62
% Permeable Surface	-1.43	3.78	9.23**
Pseudo R^2	0.98	0.98	0.98
Level 1			
Age	9.9**	9.9**	9.9**
EC	-16.24**	-16.24**	-16.24**
AIG	14.14**	14.14**	14.14**
Male	-1.37**	-1.37**	-1.37**
LEP	-6.35**	-6.35**	-6.35**
Black	-6.31**	-6.31**	-6.31**
Hispanic	-2.72**	-2.72**	-2.73**
Other Race	0.92	0.92	0.92
% Days Absent	-50.97**	-50.97**	-50.97**
Pseudo R^2	0.66	0.66	0.66
Random Effects			
τ_{00}	4.78	4.43	4.43
σ^2	160.30	160.30	160.30

NOTE: MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency; Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † $p < 0.10$. * $p < .05$. ** $p < .01$.

Table 5 (continued)

Variable	Behavioral Incidents		
	$^{1}/_{10}$ Mile	¼ Mile	½ Mile
Level 2			
Intercept	-3.52 (0.03)**	-3.48 (0.03)**	-3.45 (0.03)**
Elementary School	0.52 (1.68)*	0.54 (1.71)*	0.49 (1.63)*
City Limits	0.1 (1.11)	0.04 (1.04)	< 0.01 (1)
# Students Enrolled	< 0.01 (1)	< 0.01 (1)	< 0.01 (1)
% FRL	0.01 (1.01)**	0.01 (1.01)**	0.01 (1.01)**
% Tree Canopy	1.02 (2.77)	1.28 (3.59)	2.1 (8.14)†
% Permeable Surface	-0.38 (0.68)	-2.39 (0.09)	-2.96 (0.05)†
Pseudo R^2	0.46	0.47	0.48
Level 1			
Age	0.13 (1.14)**	0.13 (1.14)**	0.13 (1.14)**
EC	0.66 (1.94)**	0.66 (1.94)**	0.66 (1.94)**
AIG	-1.26 (0.28)**	-1.26 (0.28)**	-1.26 (0.28)**
Male	1.04 (2.82)**	1.04 (2.82)**	1.04 (2.82)
LEP	-0.38 (0.69)**	-0.38 (0.69)**	-0.38 (0.69)**
Black	1.21 (3.34)**	1.21 (3.34)**	1.21 (3.35)**
Hispanic	0.19 (1.21)	0.19 (1.21)	0.19 (1.21)
Other Race	0.1 (1.11)	0.1 (1.11)	0.1 (1.11)
% Days Absent	3.74 (42.07)**	3.74 (42.08)**	3.74 (42.08)**
Pseudo R^2	0.30	0.31	0.31
Random Effects			
τ_{00}	0.84	0.82	0.80
σ^2	2.95	2.94	2.94

NOTE: MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency; Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † $p < 0.10$. * $p < .05$. ** $p < .01$.

Table 6: Dose-Response Trends between Student Academic Functioning and Nature Indicators

Variable	MAP Scores	Behavioral Incidents
Level 2		
Intercept	212.48**	-3.38 (0.03)**
Elementary School	-13.49**	0.46 (1.59)*
City Limits	-0.34	-0.11 (0.89)
# Students Enrolled	< 0.01	< 0.01 (1)
% FRL	-0.11**	0.02 (1.02)**
% Tree Canopy	-27.8	18.35 (93407989.1)**
Tree Canopy-Squared	25.22	-16.17 (0)*
% Permeable Surface	24.33	0.38 (1.47)
Permeable Surface-Squared	-10.18	-2.22 (0.11)
Pseudo R^2	0.98	0.51
Level 1		
Age	9.89**	0.13 (1.14)**
EC	-16.24**	0.66 (1.94)**
AIG	14.14**	-1.26 (0.28)**
Male	-1.37**	1.04 (2.82)**
LEP	-6.35**	-0.38 (0.69)**
Black	-6.32**	1.21 (3.35)**
Hispanic	-2.73**	0.19 (1.21)
Other Race	0.92	0.1 (1.11)
% Days Absent	-50.96**	3.74 (42.01)**
Pseudo R^2	0.66	0.31
Random Effects		
τ_{00}	4.42	0.76
σ^2	160.30	2.94

Note: Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † $p < 0.10$. * $p < .05$. ** $p < .01$; MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency.

Table 7: Estimated Incident Rate Ratios for Significant Behavioral Incident Trends in Model 2

	Incident Rate Ratios
Very Low Canopy	3.71
Low Canopy	8.78
Average Canopy	14.12
High Canopy	15.85
Very High Canopy	12.09
Ratio Very Low to Very High	0.307

Table 8: Group Differences in the Association between Nearby Nature and Academic Functioning

Variable	FRL		Age	
	MAP Scores	Behavioral Incidents	MAP Scores	Behavioral Incidents
Level 2				
Intercept	212.61**	-3.42 (0.03)**	212.52**	-3.46 (0.03)**
Elementary School	-13.58**	0.46 (1.58)*	-13.47**	0.53 (1.7)*
City Limits	-0.51	-0.04 (0.96)	-0.39	< 0.01 (1)
# Students Enrolled	< 0.01	< 0.01 (1)	< 0.01	< 0.01 (1)
% FRL	-0.17*	0.06 (1.06)†	-0.11**	0.01 (1.01)**
% Tree Canopy	4.85	3.52 (33.89)	-2.00	2.14 (8.53)†
% Permeable Surface	0.39	0.01 (1.01)	8.26	-3.01 (0.05)*
FRL x Tree Canopy	-0.16	-0.02 (0.98)	-	-
FRL x Permeable Surface	0.18†	-0.05 (0.95)	-	-
Pseudo R^2	0.98	0.48	0.98	0.47
Level 1				
Age	9.9**	0.13 (1.14)**	9.89**	0.12 (1.13)**
EC	-16.24**	0.66 (1.94)**	-16.24**	0.66 (1.94)**
AIG	14.14**	-1.26 (0.28)**	14.12**	-1.26 (0.28)**
Male	-1.37**	1.04 (2.82)**	-1.37**	1.04 (2.82)**
LEP	-6.35**	-0.38 (0.69)**	-6.35**	-0.38 (0.69)**
Black	-6.32**	1.21 (3.35)**	-6.31**	1.21 (3.35)**
Hispanic	-2.73**	0.19 (1.21)	-2.72**	0.19 (1.21)
Other Race	0.92	0.1 (1.11)	0.92	0.1 (1.11)
% Days Absent	-50.97**	3.74 (42.07)**	-50.86**	3.76 (43.05)**
Moderator x Tree Canopy	-	-	0.83	0.24 (1.27)
Moderator x Permeable Surface	-	-	-1.94	-0.34 (0.71)
Pseudo R^2	0.66	0.31	0.66	0.31
Random Effects				
τ_{00}	4.40	0.80	4.42	0.82
σ^2	160.30	2.94	160.26	2.93

Note: Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † *p* < 0.10. * *p* < .05. ** *p* < .01; MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency.

Table 8 (continued)

Variable	EC		Age	
	MAP Scores	Behavioral Incidents	MAP Scores	Behavioral Incidents
Level 2				
Intercept	212.54**	-3.45 (0.03)**	212.54**	-3.46 (0.03)**
Elementary School	-13.53**	0.48 (1.62)*	-13.54**	0.49 (1.63)*
City Limits	-0.41	< 0.01 (1)	-0.41	< 0.01 (1)
# Students Enrolled	< 0.01	< 0.01 (1)	< 0.01	< 0.01 (1)
% FRL	-0.11**	0.01 (1.01)**	-0.11**	0.01 (1.01)**
% Tree Canopy	-2.89	2.32 (10.21)†	-2.48	2.8 (16.51)*
% Permeable Surface	9.84**	-3.14 (0.04)*	9.44**	-3.84 (0.02)*
FRL x Tree Canopy	-	-	-	-
FRL x Permeable Surface	-	-	-	-
Pseudo R^2	0.98	0.48	0.98	0.48
Level 1				
Age	9.89**	0.13 (1.14)**	9.9**	0.13 (1.14)**
EC	-16.21**	0.67 (1.95)**	-16.24**	0.66 (1.94)**
AIG	14.14**	-1.25 (0.29)**	14.14**	-1.26 (0.28)**
Male	-1.37**	1.04 (2.82)**	-1.37**	1.05 (2.85)**
LEP	-6.35**	-0.38 (0.69)**	-6.35**	-0.38 (0.69)**
Black	-6.32**	1.21 (3.35)**	-6.31**	1.21 (3.35)**
Hispanic	-2.72**	0.19 (1.21)	-2.73**	0.19 (1.21)
Other Race	0.92	0.1 (1.11)	0.92	0.1 (1.11)
% Days Absent	-50.98**	3.74 (41.97)**	-50.97**	3.74 (42.28)**
Moderator x Tree Canopy	3.05	-1.01 (0.36)	-0.27	-0.93 (0.4)
Moderator x Permeable Surface	-6.92	0.77 (2.17)	-0.4	1.16 (3.19)
Pseudo R^2	0.66	0.31	0.66	0.31
Random Effects				
τ_{00}	4.44	0.81	4.43	0.80
σ^2	160.29	2.94	160.30	2.94

Note: Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † $p < 0.10$. * $p < .05$. ** $p < .01$; MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency.

Table 8 (continued)

Variable	LEP		Black	
	MAP Scores	Behavioral Incidents	MAP Scores	Behavioral Incidents
Level 2				
Intercept	212.57**	-3.44 (0.03)**	212.59**	-3.49 (0.03)**
Elementary School	-13.55**	0.48 (1.62)*	-13.53**	0.48 (1.62)*
City Limits	-0.41	< 0.01 (1)	-0.43	0.01 (1.01)
# Students Enrolled	< 0.01	< 0.01 (1)	< 0.01	< 0.01 (1)
% FRL	-0.11**	0.01 (1.01)**	-0.11**	0.01 (1.01)**
% Tree Canopy	-1.98	2.23 (9.29)†	-0.8	0.77 (2.17)
% Permeable Surface	8.69*	-3.09 (0.05)*	7.11*	-1.72 (0.18)
FRL x Tree Canopy	-	-	-	-
FRL x Permeable Surface	-	-	-	-
Pseudo R^2	0.98	0.48	0.98	0.48
Level 1				
Age	9.89**	0.13 (1.14)**	9.89**	0.13 (1.14)**
EC	-16.24**	0.66 (1.94)**	-16.23**	0.66 (1.93)**
AIG	14.14**	-1.26 (0.28)**	14.13**	-1.26 (0.28)**
Male	-1.36**	1.04 (2.82)**	-1.37**	1.04 (2.82)**
LEP	-6.33**	-0.35 (0.71)**	-6.39**	-0.35 (0.71)**
Black	-6.33**	1.2 (3.32)**	-6.39**	1.24 (3.46)**
Hispanic	-2.73**	0.19 (1.2)	-2.77**	0.23 (1.25)†
Other Race	0.91**	0.1 (1.11)	0.91	0.12 (1.13)
% Days Absent	-51.05**	3.72 (41.16)**	-50.79**	3.68 (39.83)**
Moderator x Tree Canopy	-3.93*	-1.68 (0.19)*	-5.3	2.21 (9.1)**
Moderator x Permeable Surface	3.83†	1.9 (6.71)†	5.79	-2.02 (0.13)†
Pseudo R^2	0.66	0.31	0.66	0.32
Random Effects				
τ_{00}	4.40	0.80	4.37	0.80
σ^2	160.29	2.93	160.27	2.90

Note: Coefficients reflect unstandardized betas; behavioral incident results include incident rate ratios in parentheses; † $p < 0.10$. * $p < .05$. ** $p < .01$; MAP = Measures of Academic Progress; FRL = Free and Reduced Lunch; EC = Exceptional Child (Disability) status; AIG = Academically or Intellectually Gifted; LEP = Limited English Proficiency.

Table 9: Estimated Incident Rate Ratios for Significant Behavioral Incident Trends in Model 3

	Differences based for LEP students		Differences for Black Students	
	LEP	Non-LEP	Black	Non-Black
Low Canopy	0.08	0.22	0.61	0.08
Average Canopy	0.09	0.27	0.83	0.08
High Canopy	0.09	0.35	1.16	0.09
Ratio of Group to Non-Group	-	0.315	-	9.981

Note: LEP = Limited English Proficiency.

Table 10: Summary of Hypotheses and Results

Research Question and Hypotheses	Results	Direction
1: To what extent is nature exposure related to academic functioning?		
Greater academic performance in the context of		
a) more tree canopy	Failed to reject the null hypothesis	
b) more permeable surface	Greater MAP performance in schools with more permeable surface within a half-mile	As Expected
Fewer behavioral incidents in the context of		
c) more tree canopy	Failed to reject the null hypothesis	
d) more permeable surface	Failed to reject the null hypothesis	
2: What "dose" of nature exposure is associated with optimal academic functioning?		
Greater academic performance		
a) trend plateaus with more tree canopy	Failed to reject the null hypothesis	
b) greatest trend with least permeable surface	Failed to reject the null hypothesis	
Fewer behavioral incidents		
c) trend plateaus with more tree canopy	Greater behavioral incidents in schools with more tree canopy, and the trend plateaued	Contradicted Expectation
d) greatest trend with least permeable surface	Failed to reject the null hypothesis	
3: To what extent do certain schools or students disproportionately benefit from nature exposure?		
a) Black students will benefit more than non-Black	Disproportionately more behavioral incidents among Black students in High Canopy schools	Contradicted Expectation
b) LEP students will benefit less than non-LEP	Disproportionately more behavioral incidents among Non-LEP students in High Canopy schools; Disproportionately worse test scores among LEP students in High Canopy schools	Contradicted Expectation
c) adolescent students will benefit more than younger students	Failed to reject the null hypothesis	
d) students with disability will benefit more than non-disabled students	Failed to reject the null hypothesis	
e) male students will benefit more than females	Failed to reject the null hypothesis	
f) students in high-poverty schools will benefit most	Failed to reject the null hypothesis	

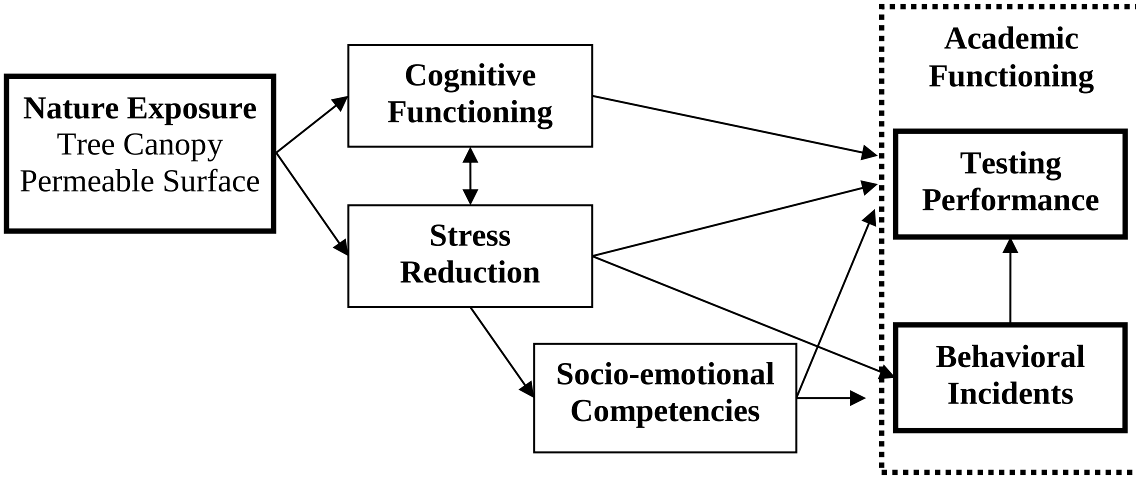

Figure 1: Conceptual Model Linking Academic Performance and Nature Exposure

Note: The present study examined direct relationships among the variables in the bold boxes

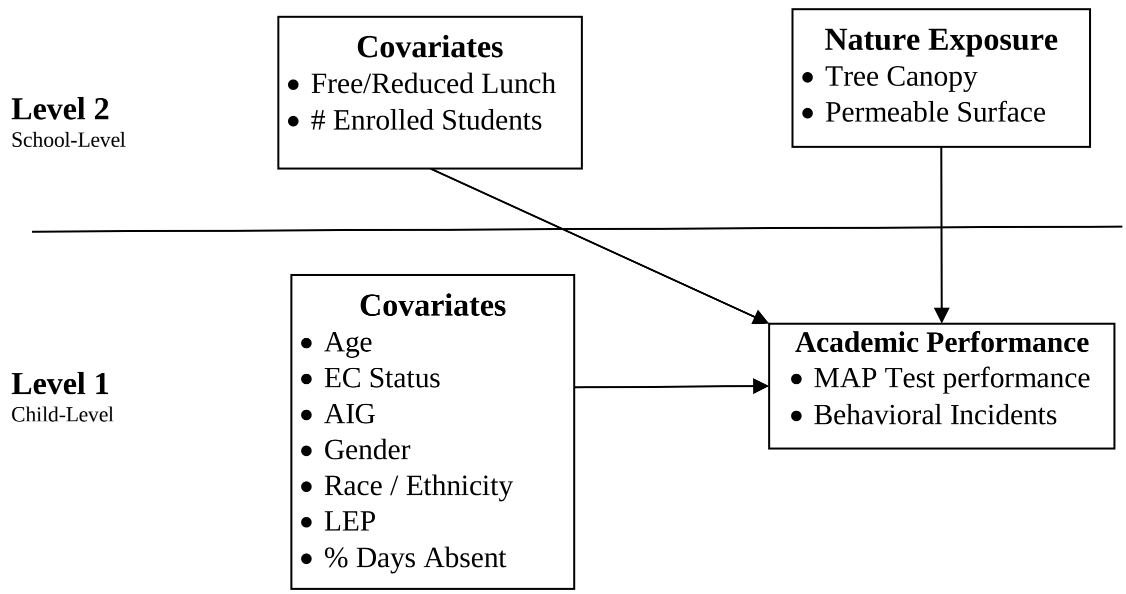

Figure 2: Model 1 - Examining the Link between Academic Performance and School Nature Exposure

Note: EC Status = Exceptional Child Status; LEP = Limited English Proficiency; AIG = Academic and Intellectually Gifted.

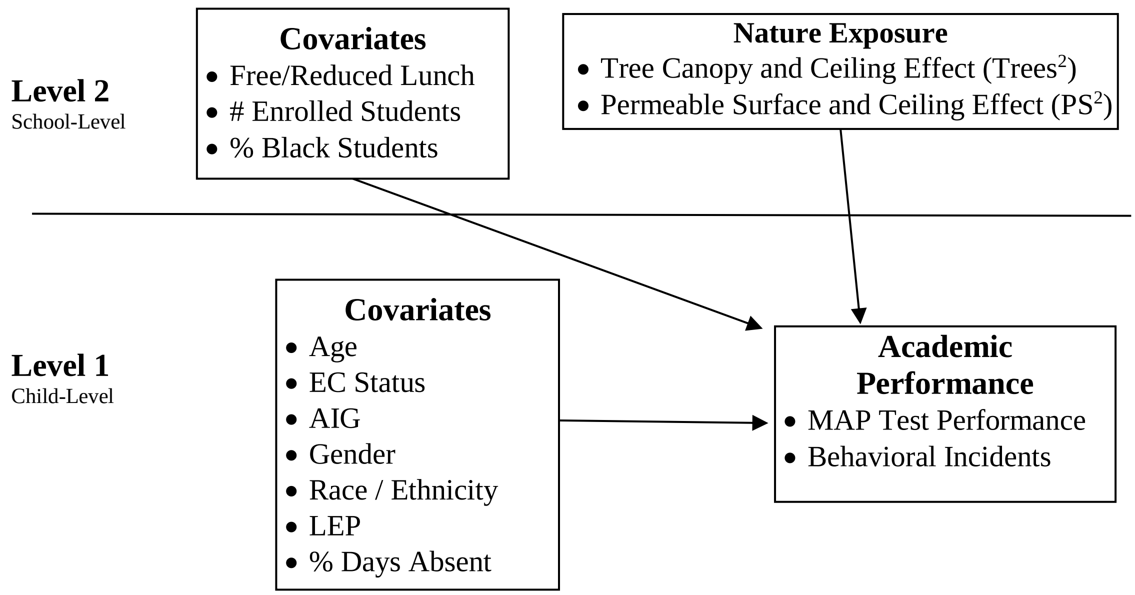

Figure 3: Model 2 - Examining the Optimal "Dose" of Nature Exposure for Enhancing Academic Functioning

Note: EC Status = Exceptional Child Status; LEP = Limited English Proficiency; AIG = Academic and Intellectually Gifted.

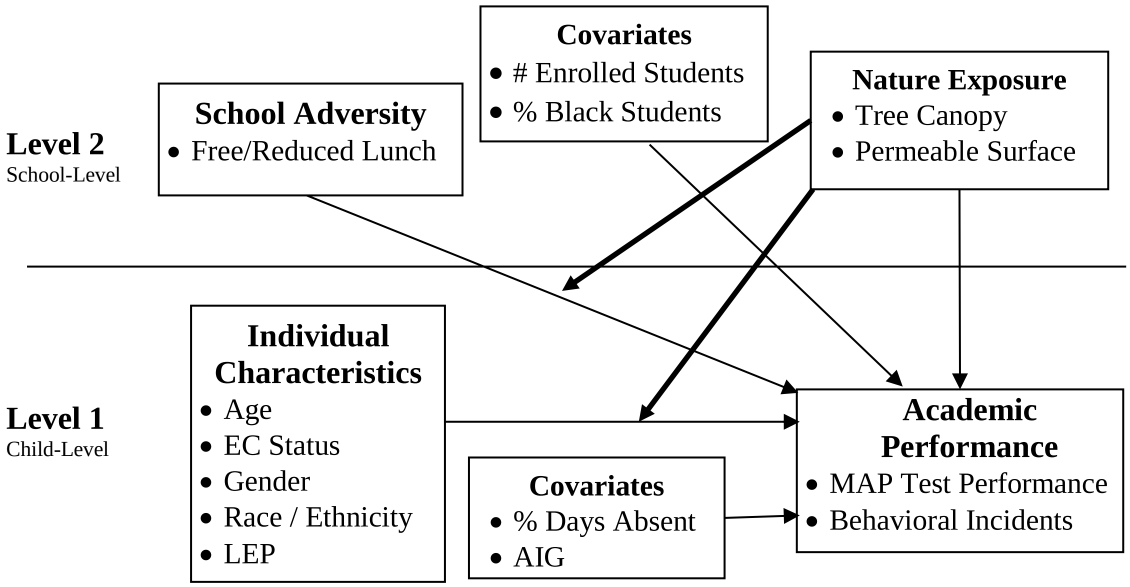

Figure 4: Model 3 - Examining Nature Exposure as a Potential Buffer to the Effects of Adversity

Note: EC Status = Exceptional Child Status; LEP = Limited English Proficiency; AIG = Academic and Intellectually Gifted.

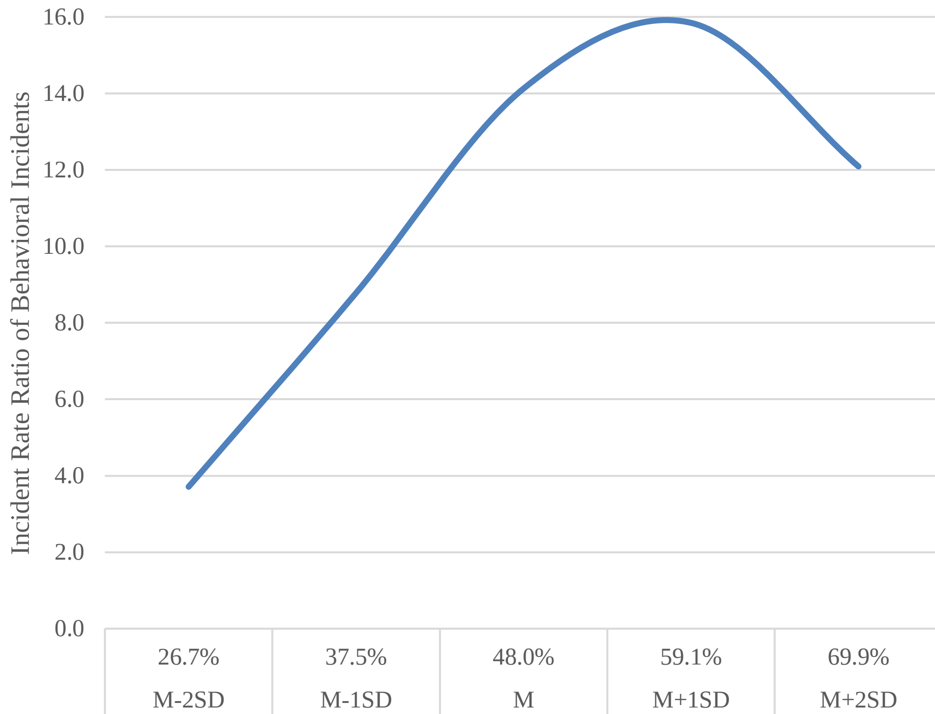

Figure 5: Dose-Response Curve for Tree Canopy and Behavioral Incidents

Note: *M* = Mean, *SD* = Standard Deviation; *M* - 2 *SD* indicates Very Low Canopy, *M* - 1 *SD* indicates Low Canopy, *M* indicates Average Canopy, *M* + 1 *SD* indicates High Canopy, and *M* + 2 *SD* indicates Very High Canopy.

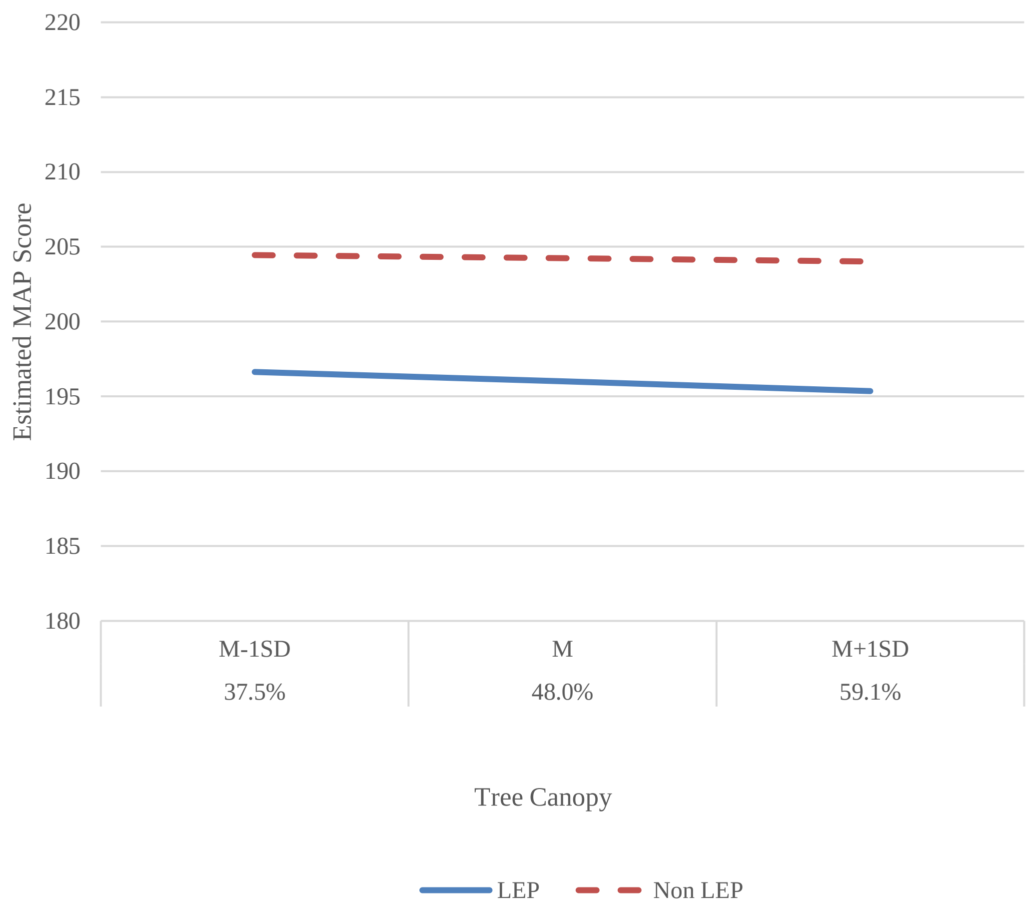

Figure 6: Differences in Association between Academic Performance and Tree Canopy based on Limited English Proficiency

Note: The range of MAP scores was restricted in this graph to display the separate lines clearly. LEP = Limited English Proficiency; MAP = Measures of Academic Progress. MAP scores range from 112 – 279.5. *M* = Mean, *SD* = Standard Deviation; *M* - 1 *SD* indicates Low Canopy, *M* indicates Average Canopy, *M* + 1 *SD* indicates High Canopy.

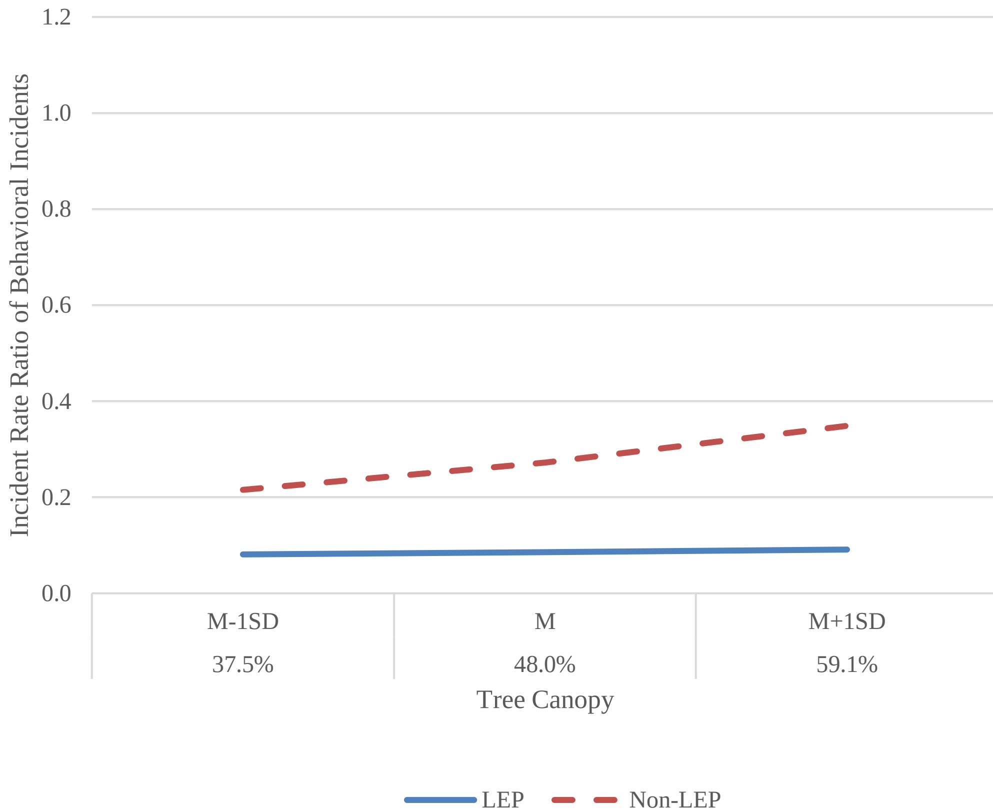

Figure 7: Differences in Association between Behavioral Incidents and Tree Canopy based on Limited English Proficiency

Note: LEP = Limited English Proficiency. *M* = Mean, *SD* = Standard Deviation; *M* - 1 *SD* indicates Low Canopy, *M* indicates Average Canopy, *M* + 1 *SD* indicates High Canopy.

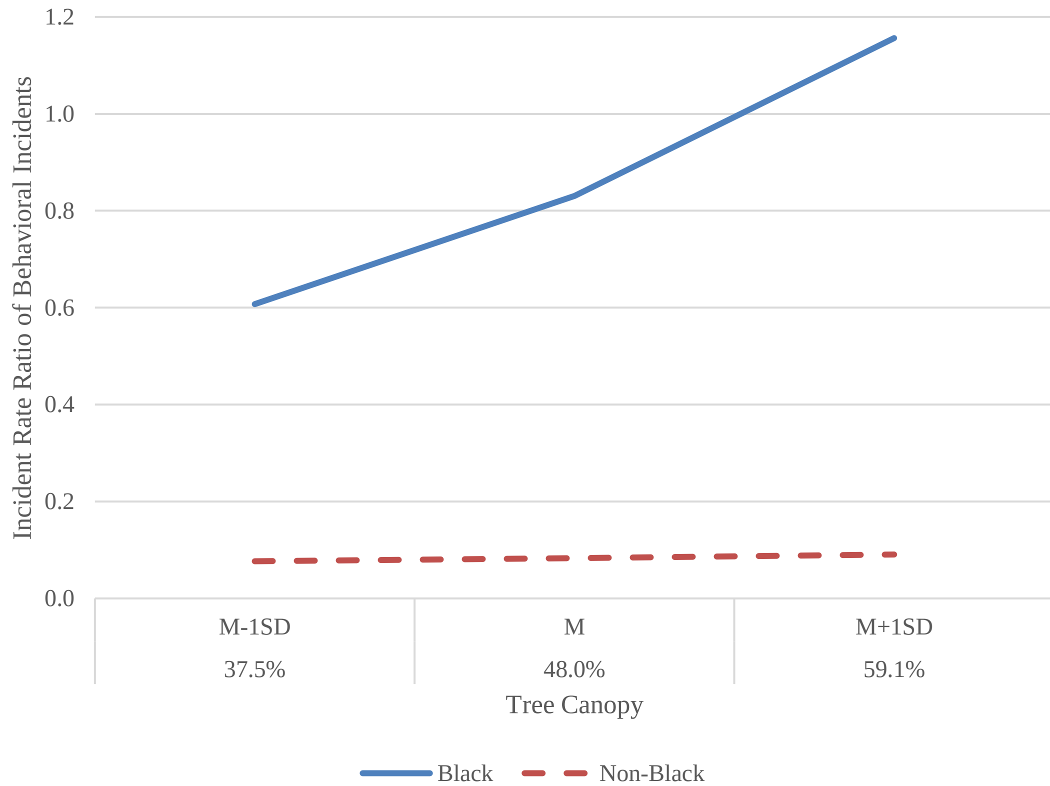

Figure 8: Association between Behavioral Incidents and Tree Canopy for Black and Non-Black Students

Note: *M* = Mean, *SD* = Standard Deviation; *M* - 1 *SD* indicates Low Canopy, *M* indicates Average Canopy, *M* + 1 *SD* indicates High Canopy.

a) Dense wooded areas

b) Evenly dispersed canopy

c) Moderately dense wooded areas

d) Relatively dispersed canopy with one nearby wooded area

Figure 9: Examples of Elementary Schools with Similar Proportions of Tree Canopy (58%) that Differ in Quality

Note: Satellite images were obtained from Google Earth®.