Original article

The link between school environments and student academic performance

Byoung-Suk Kweon [a,*], Christopher D. Ellis [b], Junga Lee [c], Kim Jacobs [d]

[a] *Department of Plant Science and Landscape Architecture, University of Maryland, 2140 Plant Sciences Building, 4291 Fieldhouse Drive, College Park, MD 20742, USA*
[b] *Department of Plant Science and Landscape Architecture, University of Maryland, 2144 Plant Sciences Building, 4291 Fieldhouse Drive, College Park, MD 20742, USA*
[c] *Institute of Life Science and Natural Resources, College of Life Sciences and Biotechnology, Korea University, 145 Anamro, Seongbuk-gu, Seoul 02841, Republic of Korea*
[d] *Department of Plant Science and Landscape Architecture, University of Maryland, 4291 Fieldhouse Drive, College Park, MD 20742, USA*

ARTICLE INFO

ABSTRACT

Healthy school environments are critical for children to learn, play, and grow. Although research focusing specifically on the benefits of green spaces on academic performance is limited, the current research does in fact point to the link between greater amounts of trees on campuses and higher academic performance. We are beginning to develop an understanding of the benefits of trees but only a few comprehensive studies have been performed that measure the effects of trees on academic achievement. We examine the relationship among green spaces, students' socio-economic factors, and their academic performance by using spatial measurements in geographic information system (GIS).

The research study included 219 District of Columbia (D.C.) public schools. School environment measurements (e.g., land cover), school demographic data (e.g., number of students, student teacher ratio and free lunch enrollment), and school performance data (e.g., DC Comprehensive Student Assessment in Mathematics and Reading) were collected and georeferenced. GIS was used to integrate spatially dependent information regarding student and environmental factors with the land cover data.

We found that schools with more trees had a higher percentage of proficient or advanced scores in Mathematics and Reading standardized tests after controlling for school size, student teacher ratio, and free lunch enrollment. However, not all types of landscapes have the same beneficial properties. Large expanses of land, "featureless landscapes," including large areas of campus lawns and athletic fields have negative effects on academic performance. These results may help to guide the decisions made by landscape architects on the basis on evidence when they plan new and renovate existing schools.

Published by Elsevier GmbH.

1. Introduction

Scientific inquiry has demonstrated the positive effects of green spaces on physical health, mental well-being, social connectivity, and human behaviors. It is now believed that we can take these concepts and apply them to education. The design of today's school buildings and spaces is beginning to reflect the values of green and healthy learning environments as communities are being incorporated more green spaces in educational facility planning and design (Hedley et al., 2004; Ozer, 2007). Although prior research discovered links between green surroundings and physical and mental health benefits (see review: McCurdy et al., 2010), only limited research has focused on the effects of green space on cognitive function specifically as measured by student academic performance. Currently, the main body of work addressing academic performance focuses on important socio-economic and demographic factors such as income, parents' education levels and occupation (Blau, 1999; Davis-Kean, 2005). To establish a more complete understanding, environmental factors such as the green spaces on school grounds should also be studied in relationship to student performance. To bridge these gaps, the research presented here investigated how potential benefits from exposure to green space can translate into a supportive environment for academic achievement for children. Our study focused specifically on

* Corresponding author.
E-mail addresses: kweonb@umd.edu (B.-S. Kweon), cdellis@umd.edu (C.D. Ellis), arch-jung@korea.ac.kr (J. Lee), kjacobs1@terpmail.umd.edu (K. Jacobs).

the role of green spaces on the public school students' Mathematics and Reading performance.

1.1. Research background

The restorative mental and psychological benefits of green landscapes have been widely theorized and researched; such benefits may play an important role in student performance. Psychologically, green landscapes have been shown to lower stress (Hartig et al., 1991), foster an overall sense of well-being (Ulrich et al., 1991), and reduce depression (Bowler et al., 2010).

Green landscapes also plays an important role in concentration and focus. There are two theories to explain this relationship: attention restoration theory and stress reduction theory. Attention restoration theory can easily apply to school environments that require students to assert a great amount of prolonged mental effort, which can lead to what Kaplan calls direct attention fatigue (Kaplan, 1995). When students become mentally exhausted, they may display irritable behaviors, agitation, and may have trouble concentrating or performing simple tasks. Such fatigue can be detrimental to students' ability to perform well academically. Green landscapes may provide an antidote for attention fatigue. Several studies have shown that spending more time in green space or even views of green landscapes can improve both direct attention and performance (Bratman et al., 2015; Cimprich, 1992; Li and Sullivan, 2016; Taylor et al., 2001a). Students who are able to focus and concentrate on class materials will absorb content more effectively and be able to perform better on assessments. Children who moved to greener environments had highest levels of cognitive functioning following the move (Wells, 2000). Also, children with attention deficits had better attentional functioning after spending their time in green outdoor spaces (Taylor et al., 2001b) and better concentration performance after walking in a park (Taylor and Kuo, 2009). These research studies indicate that nature affects children's cognitive functioning and suggest that school greenness might also link to higher student cognitive functioning.

The second theory, stress reduction theory explains how unthreatening forms of nature can help to reduce stress more than built environments (Ulrich et al., 1991). Previous research findings indicate that exposure to natural elements such as trees and shrubs plays an important role in reducing stress (Jiang et al., 2015; Ulrich et al., 2003). Even short exposure (5 min) to nature produce positive changes (Barton and Pretty, 2010). Today's students can face stress for a variety of reasons, and nature or green landscapes may help to relieve it.

Exposure to outdoor green spaces may also improve students' academic outcomes. Researchers who have investigated the potential of green school grounds as outdoor classrooms have discovered that students find an outdoor, nature-centered environment for education much more meaningful than an indoor, book-centered environment (Dyment, 2005). Outdoor learning lends itself toward informal learning, where students are free to learn from exploring their surroundings. Students are intrinsically motivated to learn without teacher intervention (Adams, 1993). Academic outcomes of garden-based learning have largely been found to be positive for both direct (e.g., course assessment) and indirect (e.g., social development) measures (Williams and Dixon, 2013). A randomized experiment (Wells et al., 2015) concluded that the intensity of a garden-based learning intervention led to improved knowledge scores in science. One might suggest, then, that green spaces may create motivational environments that foster greater bonds between students and their learning environments, allowing students to place greater importance on their education and academic success.

Views to green space is another important effect. Researchers have studied the effects of proximity to—and views of—green space in several different realms, including prisons (Moore, 1981), hospitals (Curtis et al., 2007; Raanaas et al., 2012), elderly homes (Ottosson and Grahn, 2005), office settings (Jahncke et al., 2015; Lottrup et al., 2013), and residential neighborhoods (Jiang et al., 2015). A few studies focused specifically on the effects of green space views on children. For example, girls with views of green space had better concentration, impulse inhibition and self-discipline then those without views of green space (Taylor et al., 2001a). Students with views to green space improved on attention tests and recovery from stress (Li and Sullivan, 2016). These types of effects are relevant when considering academic performance, as most students spend the majority of their time indoors. What's more, research shows that ample classroom window views of trees and shrubs are associated with higher scores on standardized test scores (Heschong Mahone Group, 2003). If student performance is enhanced simply from a view of green landscape, there is reason to believe that achievement may be enhanced through interaction with green landscapes as well.

Although research focusing specifically on the academic benefits of green space is limited, two recent studies (Wu et al., 2014; Matsuoka, 2010) do in fact point to the link between greater amounts of vegetated spaces on campuses and higher academic performance. Wu et al.'s (2014) study of Massachusetts's public schools, the first study to investigate the link between surrounding greenness and school-based performance scores using remote sensing techniques, indicates a positive association between school greenness and student academic performance. Researchers used the composite scores from the Massachusetts Comprehensive Assessment System (MCAS) to measure the number of elementary school students who scored "above proficient" in the English and Mathematics tests. The study used Normalized Difference Vegetation Index (NDVI) data from March and October, times when students are in school, to calculate the "greenness" of 905 Massachusetts public schools. The "greenness" measure did not distinguish between different types of green (tree, grass, and shrub) which is an important difference with the study presented here. The results of the Wu et al. study indicate that students with higher exposure to green space demonstrate higher academic performance than students with lower exposure.

Matsuoka's study of 101 Michigan public high schools also found an association between exposure to green landscape during the school day and academic performance scores. The study measured exposure to green space, views of green space, vegetation levels on campus, and potential access to green space to understand the "greenness" levels of each school. Academic performance measures aggregated to the school level were based on the Michigan Merit Award, graduation rates, and four-year college plans. Results of the study support the proposition that increased exposure to green space throughout the day is positively associated with school performance. Schools that provided greater access to green space and enabled more time outdoors achieved better standardized test scores, had higher graduation rates, and were more likely to have students with plans to attend a four-year college (Matsuoka, 2010).

Some important limitations to Matsuoka's study that are relevant to the study presented here include the sample size and the grade ranges of the students studied which affect external validity. Matsuoka sampled only a subset of all public high schools in Michigan (101 of approximately 700 high schools) and performance measurements were limited to ninth grade students only as that is the only time Michigan administers standardized tests in high schools.

Also, research suggests that not all types of landscapes have the same beneficial effects. Large expanses of land, "featureless landscapes," including large areas of campus lawns, athletic fields, and parking lots, have negative effects on academic performance. Matsuoka's (2010) study showed that, while the presence of trees