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The effectiveness of a head-heart-hands model for natural and environmental science learning in urban schools

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ABSTRACT

We describe an environmental and natural science program called Nurture thru Nature (NtN) that seeks to improve mathematics and science performance of students in disadvantaged communities, and to increase student interest in Science, Technology, Engineering and Mathematics (STEM) careers. The program draws conceptual guidance from the Head-Heart-Hands model that informs the current educational movement to foster environmental understanding and sustainability. Employing an experimental design and data from seven cohorts of students, we find some promising, albeit preliminary, indications that the program can increase students' science knowledge and grades in mathematics, science and language arts. We discuss the special adaptations that environmental and sustainability education programs need to incorporate if they are to be successful in today's resource depleted urban schools.

1. Introduction

The need for individuals who possess skills in science, technology, engineering and mathematics (STEM) has never been greater in our country. Yet as recent reports from both business and government sectors indicate, millions of these STEM jobs remain unfilled in large measure because of a skills shortage in America's labor market (U.S. Congress Joint Economic Committee Report, 2012; U.S. Department of Commerce, 2011). In a 2015 report to Congress, the Committee on Equal Opportunities in Science and Engineering (2015) identified poor elementary and high school education as one of the major reasons that STEM careers are ignored, dismissed or abandoned. This dynamic is especially prominent among minority students in our inner cities.

Since the early 1990s the achievement gap between white students on the one hand, and black and Hispanic students on the other, has remained disturbingly large (National Center for Education Statistics, 2013). Much of the available research indicates that this gap widens over time, is accelerated over the summer break, and is not limited to cognitive skills, but affects non-cognitive skills as well (Heckman, 2013; Fryer and Levitt, 2004). A consensus has also emerged that interventions to improve academic performance are best targeted at younger (elementary) school students; these interventions do not face the equity-efficiency tradeoff characterized by programs for adolescents (Heckman, 2013; Heckman and Masterov, 2008).

In this paper we report results from an evaluation of the Nurture thru Nature (NtN) program in seven elementary schools serving disadvantaged black and Hispanic students in Central New Jersey, USA. NtN is a natural/environmental science initiative that attempts to improve the basic science, mathematics and language arts performance of disadvantaged elementary and middle school students and use this improvement as a platform for stimulating interest in STEM disciplines and careers. The program is inspired by the "Head, Heart and Hands" environmental educational model articulated by Singleton (2015) which has its roots in the active learning philosophy of John Dewey (1976,1990. The NtN program is designed as a classical experiment with random assignment to treatment and control groups and operates as an after-school as well as a summer enrichment program. NtN makes active use of the aesthetics readily found in nature to excite student imagination and engender a deeper scientific understanding of the interconnections among persons, community and the environment.

2. Background literature

There is a growing consensus among educators in the sustainability movement that "hands on" environmental and natural science teaching opens pathways for young students to STEM and green careers (Aikens, McKenzie, & Vaughter, 2016; U.S. Department of Education, N.D.). Inasmuch as a good deal of the literature has been discussed elsewhere (Camasso & Jagannathan, 2017), we provide a brief synopsis here.

Lieberman and Hoody (1998) have evaluated the influence of a

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curriculum called Environment as Integrating Context in 40 elementary, middle and high schools from across the United States. The researchers report higher Grade Point Average (GPA), language arts, mathematics, and science grades for elementary and middle school students. Garden and outdoor-based, nature curriculum has also been reported to increase student achievement in several additional studies (Gaylie, 2011; Hirschi, 2015; Royal Horticulture Society, 2010). Critics of this research (Blair, 2009; Williams & Dixon, 2013) note that many of the findings of this research are compromised by weak research designs, short follow-up periods, lack of a clear counterfactual and absence of controls for teacher effects.

After-school programs designed to improve the reading, mathematics and science performance of disadvantaged students have become an increasingly popular approach to bridging the achievement gap. Despite widespread praise, the effectiveness of these programs remains unsettled. Hollister (2003), Fashola (1998), Lauer et al. (2006), among others, assert that the evaluation literature on after-school programs is plagued by poor conceptualization, weak design, and publication outside the perimeter of peer reviewed journals.

In their sweeping review of the 150 evaluations of after-school programs listed by the Harvard Family Research Project that includes such highly publicized endeavors as the 21st Century Community Learning Centers, Big Brothers, Big Sisters, and the Quantum Opportunities program, Levine and Zimmerman (2010) report a preponderance of disappointing results. In the rare instances where math or reading effects are found to be significant, most effects disappeared after a one year follow-up.

Efforts have also increased to combat the problem of "summer fallback," i.e., abrupt increases in the size of the achievement gap that occur after summer recess (Alexander, Entwisle, & Olsen, 2007; Hanushek & Rivkin, 2009). While results from evaluations of summer programs like Building Educational Leaders for Life have been promising, mathematics effects, especially, have been exceedingly small and never statistically significant (Somers, Welbeck, Grossman, & Gooden, 2015). Evaluators here have attributed the dearth of positive effects to the problem of "underpowered treatment," i.e., low dosages of program treatment due to recruitment issues, weak research designs, short treatment periods and low student attendance (McCombs et al., 2011; Somers et al., 2015; Robinson-O'Brien et al., 2009). The problem of underpowered treatment would also appear to be a factor in evaluations of enhanced science/math curriculum and after-school programs as well.

3. The NtN intervention

3.1. Conceptual framework

Nurture thru Nature (NtN) attempts to overcome the limitations of some environmental science interventions targeted at disadvantaged youth through a program of clear conceptualization of purpose, sufficient treatment dosage, and strong evaluation design. NtN draws heavily from the seminal work of John Dewey, recognizing that children are never passive recipients of education but rather are actively engaged agents in their own life's dramas. There is an additional recognition that young students, regardless of background or family resources, have a wellspring of uninvested human capital that can be directed into communication, construction, inquiry, and abstract thinking if teaching takes a personal approach, understanding how student interests and habits derive from their homes and neighborhoods (Dewey, 1976:p.30; Dewey, 1990:p.463). In many ways, NtN is quite congruous with the "Head, Heart and Hands" model for transformative learning articulated by Singleton (2015).

As described by Singleton (2015), the "Head, Heart and Hands" model for transformative learning, as inspired by Dewey, is designed to promote student learning through the simultaneous involvement of intellect, emotion and body. In her own words:

> "The model shows the holistic nature of transformative experience and relates the cognitive domain (head) to critical reflection, the affective domain (heart) to relational knowing and the psychomotor domain (hands) to engagement. This model not only represents the multi-dimensional nature of transformative processes, it also includes the importance of learning context. The context of place provides a framework of authentic experience for deeper reflection, sense of belonging and body/sensory stimulation that acts as a catalyst for deep engagement."

What the Head, Heart and Hands model fails to do is to fully incorporate the reality of a resource depleted school environment into its conceptualization of learning context. In the authors' experiences working with inner-city schools, we find the need to approach transformative learning from an underlying Maslowian template. Rather than apply the "Head, Heart and Hands" model as a non-recursive intervention with focus more-or-less evenly spread across cognitive, emotional and psychomotor domains, the exigencies and realities of the under-resourced urban school compel a hegemonic emphasis on cognitive learning. Because of the political and economic necessities described below, NtN can most accurately be described as a HEAD, Heart and Hands approach to environmental and sustainability education.

3.1.1. Core program components

The NtN program, initiated in 2010, is a partnership of Rutgers University faculty and students, the New Brunswick School District, and Johnson & Johnson. NtN was designed after a careful review of extant research on nature-based and environmental education. This literature pointed to a set of program inputs and activities that could be conceptually linked to improved academic performance for students. The program structure and operations of NtN were specifically designed to overcome the problem of "underpowered treatment" and the low dosage exposure it presaged. The structure intertwines 11 key components, of which 5 are of central importance, viz., a natural science curriculum aligned with the curriculum taught by public school science and math teachers; after-school and summer components that continued and reinforced school curriculum; math, language arts and science tutoring; the use of garden/naturescape assets that extended classroom teaching and provided opportunity of more in- depth and supplementary science learning, and a commitment to keep parents aware and involved in their child's math and science education. These inputs, activities and expected outcomes are shown in Fig. 1 in the form of a logic model. The logic model also calls for the assessment of program impact on longer term outcomes in addition to the short and medium term outcomes that we focus on in this paper.

During the academic year, project-based learning and hands-on experiments support an NtN natural science and math curriculum that is aligned with the curriculum taught in the New Brunswick public schools. The academic year NtN curriculum is delivered after school for 3 h a day, 2-days a week. During the summer months of July and August, NtN continues the natural science curriculum enriched with more hands-on exercises for 7.5 h a day, 3 days a week. Fig. 2 presents some examples of the science topics receiving emphasis in grades 4 through 8. Classroom teaching on these topics are augmented with direct experiences in each grade.

Although NtN is focused on environmental and natural science education, time is reserved in each session to help students achieve advanced proficiency in both language arts and mathematics. Students receive reading assignments and problem sets with a natural science content, that are graded and discussed with students, individually or in small groups. Periodic assessments at the end of each science topic module are also conducted by NtN staff.

NtN summer and after-school instruction makes heavy use of the school naturescape/garden, a resource that offers a place for observation and identification, quiet reflection, hypothesis testing, and problem solving. The basic architecture of an NtN naturescape appears in Fig. 3