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Improving academic outcomes in poor urban schools through nature-based learning

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ABSTRACT

This paper presents results from the evaluation of the Nurture thru Nature (NtN) programme, a natural science and environmental education intervention designed to help elementary school children from disadvantaged backgrounds increase their knowledge of science and strengthen overall academic performance. Using an experimental design the pilot NtN programme in New Brunswick, NJ was assessed in one elementary school for a period of four years. The evaluation revealed that NtN students ($n = 18$) consistently outperformed a group of controls ($n = 34$) in mathematics and science with the differences in science reaching statistical significance. The paper discusses the active learning philosophy that motivates NtN teaching, the programme components that operationalise this philosophy, and a natural history paradigm from which this philosophy derives.

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Introduction

There is broad agreement in the United States that far too many children from disadvantaged families are performing below expected grade level in our public schools. Student academic problems have been traced to a wide range of often highly contested causes including inadequate programme funding, poor or unqualified teachers, low levels of parental involvement, frequent household moves and student obligations to work and care for family members. Inadequate academic preparation in school places these children at a significant disadvantage for success in higher education and in the labour market (Carneiro & Heckman, 2003; Heckman, Stixrud, & Urzua, 2006; US Department of Commerce, 2011).

Nowhere in the school curriculum is poor performance more pronounced than in maths and science courses where highly qualified teachers are in shorter supply (Grissmer, Flanagan, Kawata, & Williamson, 2000). Proficiency with this subject matter is essential if a student plans on entering a Science, Technology, Engineering or Mathematics (STEM) related career or the health professions, both expanding economic sectors with the promise of well-paying jobs. The US Government Accountability Office (2006) has documented the significant underrepresentation of young African-American and Hispanic women and men

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in STEM jobs and point to poor elementary and high school education as a key factor that discourages the pursuit of these careers.

In this paper we present results from an examination of the Nurture Thru Nature (NtN) programme, an intervention designed to help elementary school children aged nine to 13 from disadvantaged backgrounds increase their knowledge of science and strengthen their overall academic performance. Two research questions are posed: Does the NtN programme, with its primary focus on introducing students to the wonders of nature and natural science, increase classroom achievement in science, mathematics and language arts? In addition, does the NtN programme increase students' knowledge of nature and natural science? NtN differs from most science programmes operating in low socioeconomic and minority-concentrated school districts in three ways. It traces its genesis to the active learning philosophy articulated by John Dewey (1976, 1990) and to arguments for an ecologically sustainable education advanced by Sterling (2009), Clarke (2012) and others. A second feature of NtN that distinguishes the programme is a reliance on experimental design, an evaluation timeframe that permits the assessment of both short-term and longer run effects and the measurement of impact on a combination of academic and civic skills. But perhaps the most important difference is NtN's adoption of a natural history paradigm that stresses the beauty and majesty of the natural environment and its capacity to teach as well as comfort.

The inner-city, public school achievement gap

Urban public schools in America provide education under the withering spotlight known as the achievement gap. After a period in the late 1980s and early 1990s when it appeared that the achievement gap between white and black students and white and Hispanic students was narrowing, in the mid-1990s the white–black achievement gap began, once again, to grow (Grissmer et al., 2000; Hanushek & Rivkin, 2009). More recent data from the National Center for Education Statistics (2013) indicates that this gap may once again be narrowing a bit; however, the differences between white and minority students in both science and mathematics remain disturbingly large. For white and black students aged nine years, the average difference on the National Assessment of Educational Progress (NAEP) was 23 points in reading and 26 points in maths in 2013. The gap between white and Hispanic students was 21 and 17 points. NAEP results for 13- and 17-year-olds show much the same differences.

Some careful analyses of achievement differences by race and socioeconomic class have resulted in three important insights, namely, educational deficits are cumulative, they are accelerated in the summer, and these accumulating deficits are not limited to cognitive skills.

Fryer and Levitt (2004), Heckman (2013) and Heckman and Masterov (2008) report that the already substantial achievement gap between disadvantaged and more privileged students at entry to school increases with age. Some of this increase has been linked to school resources; however, a substantial amount of the increase appears to occur within schools, regardless of resources. Because of this accumulating effect, labour economists and child development experts alike have called for 'predistribution' or early intervention strategies in academically adverse environments. Heckman (2013) sums up this growing consensus when he asserts that 'programs targeted toward the adolescent years of disadvantaged youth face an equity–efficiency tradeoff that programs targeted toward the earlier years of the lives of disadvantaged children avoid' (p. 40).

It has also become quite clear that increases in the white–minority achievement gap are not ‘steady-state’; abrupt increases in the size of the gap occur after each summer recess (Alexander, Entwisle, & Olson, 2007; McCombs et al., 2011). Hanushek and Rivkin (2009) note that a consistent finding in the research literature is the phenomenon of ‘summer fall back’, which suggests that while learning during the school year might, on average, be the same for whites and minority students, the amount of learning in the summer months heavily favours white students (p. 370).

Learning deficits have been shown to occur in a series of socio-emotional regulation skills as well. Carneiro and Heckman (2003) assert that a series of ‘soft skills’, or civic skills, e.g. perseverance, attentiveness, motivation, self-confidence, self-discipline, trustworthiness, and dependability, are developed early in a child’s life and are as important as cognitive skills for success in school, the labour market, and in life. Ability gaps between white and minority children on ‘soft skills’ when combined with low scholastic performance helps to ensure that the lives of disadvantaged children devolve into the lives of disadvantaged adults (Heckman, 2013; Heckman & Masterov, 2008).

Short of new efforts to address the achievement gap through legislative and/or judicial desegregation (see Chetty & Hendren, 2015; Chetty, Hendren, & Katz, 2015; for example, for the implications of Moving to Opportunity and other residential mobility research) policy and programming initiatives have focused on improving education in poor performing schools. Moreover, innovative programmes that do not explicitly address student deficits in mathematics, science, or language arts have had a rapidly diminishing probability of adoption in these schools as high-stakes testing plays an increasingly prominent role in budgetary decisions (National Education Association, 2014; Nichols, Berliner, & Noddings, 2007).

Environmental science education as a path forward

One approach to increasing student performance in science and maths has manifested itself through the environmental and sustainability education movement (Clarke, 2012; Sterling, 2009). Here the provision of effective robust environmental and ecological teaching is viewed as a pathway to STEM and green careers and to the inculcation of civic skills and values fundamental to the long-term health of society (US Department of Education, n.d.). Three principal initiatives have been employed by school districts, i.e. the intensification/enrichment of curriculum, after-school programmes that concentrate on maths, and science learning and summer ‘learning loss’ prevention endeavours. Reforms like longer school days, longer school years, and more intensive teacher training in STEM have not been serious options in the United States notwithstanding recommendations from several blue-ribbon panels (National Commission on Excellence in Education, 1983; US Department of Education, 2008).

Science-suffused curriculum

The impetus for substantially increasing the prominence of science in elementary and middle school curricula can be traced to several important government and foundation reports with two that were especially influential. Lieberman and Hoody (1998) tested the influence of a curriculum they call the Environment as Integrating Context (EIC) model in 40 elementary, middle and high schools from across the United States. Interviews were done with more than 400 students and 250 teachers and these data were used to provide a context for analyses conducted in 14 schools that directly compared the academic outcomes of students taught with EIC and students taught with a traditional curriculum. These researchers report higher GPAs, language arts, maths, and science grades for elementary and middle school students receiving EIC and an overwhelmingly positive response to EIC by teachers. In a second study, the Royal Horticulture Society (RHS) (2010) surveyed 1300 teachers from across Great Britain and examined in depth the effect of school garden-based environmental education on science learning in 10 schools. The RHS finds evidence that gardens increase student achievement through the creation of (a) a readiness to learn; (b) a resiliency in effort; and (c) an inculcation of personal responsibility and ownership.

A garden- and outdoor-based curriculum has become an increasingly popular vehicle for addressing disadvantaged student performance challenges ranging from poor science and maths grades to unhealthy nutrition attitudes and eating behaviour. Gaylie (2011) notes that 'evidence is overwhelmingly positive in the ways school gardens contribute to students' academic achievement' (p. 4). Research by Klemmer, Waliczek, and Zajicek (2005) and Smith and Matsenbocker (2005) would appear to bolster this claim. Both studies, which employ strong evaluation designs, report statistically significant impacts of hands-on gardening on science achievement tests. Jane Hirschi (2015) in her recent book reports on more anecdotal evidence that school gardens positively impact students' academic achievement and behaviour (p. 18). She profiles the work of five US programmrs, namely, City Sprouts (Boston), the Boston Schoolyard Initiative, Real School Gardens (Texas), Education Outside (San Francisco), and the OSSE School Garden Program (Washington, DC). A post by Erbentraut (2015) entitled 'School Gardens Can Help Kids Learn Better and Eat Healthier. So Why Aren't They Everywhere?' provides a concise summary of the sentiment that 'hands on' environmental education can bring science alive for students and teachers alike.

When the accumulating evidence is examined closely, however, it becomes clear that the effectiveness of an environmental-based curriculum, whether primarily in-class only or complemented by garden exposure, cannot be unconditionally confirmed. For example, in their review of 48 studies of 'garden-based pedagogy' Williams and Dixon (2013) conclude that while over half of these report support for either direct academic improvement and/or indirect effects like social development, environmental empathy, or nutritional knowledge, virtually all lack research rigour in sampling techniques, establishing a counterfactual or discussing threats to internal validity. In her review of 20 studies, Blair (2009) remarks that while nearly all studies report school gardening impact on either science achievement or food/nutrition attitudes and behaviours these conclusions are compromised by weak research designs, no or short follow-up periods, the absence of controls for teacher effects and a reliance on assessment questionnaires instead of actual grades or test scores. It is clear from these reviews and others like them (Robinson-O'Brien, Story, & Heim, 2009) that this emerging area of research will greatly benefit from a regimen of quantitative and qualitative evaluations that clearly focus on measures of success and the practices that ensure this success is managed and maintained.

After-school programmes

The work of after-school tutoring and homework programmes like the 21st Century Community Learning Centers (CCLC) and Big Brothers, Big Sisters in the United States are generally applauded as important efforts to improve the reading, maths and science grades of disadvantaged and minority youth. Notwithstanding the widespread praise, the effectiveness of such endeavours is far from settled. Robert Hollister (2003), in a paper commissioned by the Brookings Institution, concludes that we really do not know much about the efficacy of these programmes, a conclusion that is reiterated in reviews by Fashola (1998) and Lauer et al. (2006). The consensus among these researchers is an evaluation literature characterised by poor conceptualisation, weak design and publication outside the perimeter of peer-review journals.

Levine and Zimmerman (2010) find that only nine of the 150 evaluations of after-school programmes listed by the Harvard Family Research Project were evaluated using an experimental design. They assert that 'this highlights the fact that there is a limited research base from which to draw in forging an assessment of the efficacy of after-school programs' (p. 125).

The limited experimental evidence points up a good deal of incongruence between a popular perception of after-school programme effectiveness and an empirical reality of far more modest accomplishment. The national evaluation of the 21st CCLC undertaken by Mathematica from 1999 to 2003 found no effect on maths and reading test scores or on English, science or maths grades. In addition, behavioural problems were higher in the CCLC group than among students in at-home or self-care circumstances. A study by Public/Private Ventures of 10 Big Brother, Big Sister Agencies did find some effects on language arts and science classwork and homework, but these effects largely disappeared at a one-year follow-up. A Mathematica evaluation of the Quantum Opportunities Program (QOP) (1995–2001) reports similarly disappointing results with no significant differences between QOP and control groups in achievement test scores, grades, high school graduation rates or behavioural issues in school (see Levine & Zimmerman, 2010 for a more detailed discussion of these evaluations).

Summer learning loss prevention

Intensive science and maths programmes, typically offered to elementary and middle school students aged seven to 14 in July and August, are increasing in number and scope in disadvantaged school districts. As in the cases of after-school programmes and science-intensive curricula the empirical record of summer programme efficacy is thin. A recent report issued jointly by the Wallace Foundation and RAND reports that mathematics skills appear to be particularly at risk because of 'summer learning loss' (McCombs et al., 2011). Lack of strong conceptualisation and research designs is once again identified as an obstacle to an accumulation of knowledge that would help educators design summer programmes capable of improving science and maths classroom performance. The Report identifies only four studies that have evaluated summer programmes with an experimental design and these indicate an average effect size (ES) of a modest +0.14 standard deviation units.

Evaluations of the Building Educational Leaders for Life (BELL) elementary and middle school summer programmes, conducted by the Urban Institute and MDRC, using randomised experiments, find some 'suggestive' evidence of reading and maths score improvement (Somers, Welbeck, Grossman, & Gooden, 2015). The maths effects, however, are exceedingly small and are never statistically significant for this five-week, five days a week, 6.5 h per day intervention. Somers and her colleagues (2015) state that the small effect sizes could be a function of recruitment issues, the short treatment period and student attendance. These problems coupled with low levels of parent and teacher involvement are not limited to summer programmes but affect the functioning of enhanced curricula and after-school programmes as well. They result in the delivery of lower dosages of treatment, the possibility of treatment effect attenuation, and what Somers et al. (2015) label the 'underpowered study' (see also McCombs et al., 2011; Robinson-O'Brien et al., 2009).

The apparent failures of these many environmental and sustainability initiatives to address summer learning loss may not simply be the result of implementation issues; rather, the disappointing academic outcomes could be the consequences of a failure to infuse instruction with a sufficient level of excitement and wonder. Bonnett (2013) would seem to diagnose some of the problem as an environmental science suffused with 'scientism', i.e. speciesism, instrumentalism and consumerism, but bereft of intimacy or connectedness. It could be hypothesised, as Orr (2004) does, that real intelligence, including knowledge of mathematics and science, grows with an applied ecological intelligence centred on such qualities as silence, humility, beauty and restoration (p. 52).

The NtN science programme

The strategic vision of NtN was perhaps best captured in a brief preface to the programme's first brochure:

> We designed the Nurture thru Nature program as a vehicle capable of transporting young students into the world of exploration, excitement and wonders that we experienced growing up as elementary school children. This world was not very big – extending through the immediate neighborhood and on occasion reaching across town to a grandparent's or relative's home and garden. Though small in size our neighborhood was not puny in opportunities for adventure – colorful birds and butterflies that needed to be identified; fruits, berries and strange vegetables that merited tasting; dangerous looking snakes, frogs, and insects that had to be touched; fish requiring catching and flowers that enticed through their scent and beauty. Our explorations moreover found us continually bumping up against many of the principles of natural and physical science: e.g. photosynthesis, animal migration, natural selection, habitat change and adaptation, health and disease. We believe that the journey into our natural world needs to begin at a young age and that it must be supported by teachers and parents in the classroom and at home. (Camasso & Jagannathan, 2009)

NtN structure and daily operations intertwine five key components, i.e. a natural science curriculum aligned with the curriculum taught by public school science and maths teachers; after-school and summer components that continued and reinforced the school curriculum; maths, language arts and science tutoring; the use of garden/naturescape assets that extended classroom teaching and provided opportunities for more in-depth and supplementary science learning; and a commitment to keep parents aware and involved in their child's maths and science education. The NtN website (http://www.ntn.rutgers.edu) provides more detailed information on these components.

Although NtN is focused on natural science education and ecology, 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, typically with a natural science content, that are graded and discussed with students, individually or in small groups.

NtN summer and after-school instruction makes heavy use of the school naturescape/garden, a place that offers a place for observation and identification, quiet reflection,

Figure 1. An NtN naturescape.

hypothesis testing, and problem-solving. The basic architecture of an NtN naturescape appears in Figure 1 with the principal components comprising an arched entranceway, a water feature (typically a pond with waterfall), butterfly and caterpillar gardens, an organic vegetable garden, and a composting station. In addition to serving as an oasis for nature in the schoolyard and a centre for scientific inquiry, NtN naturescapes provide a venue for bringing families and neighbours together.

NtN naturescapes provide students with the setting to study insects, flowers, trees and birds in situ. Learning here ranges from classification and species identification to the understanding of complex processes like metamorphosis, pollination, parasitism and niche changes. Water features extend this learning to fish, amphibians, aquatic plants and pond microorganisms. The organic garden opens up instruction in the areas of fruit and vegetable cultivation, basic horticulture, plant pests, hybridisation and nutritional value.

NtN instructors include faculty and students (graduate and undergraduate level) from a wide variety of disciplines at Rutgers University in an attempt to operationalise Dewey's 'University Elementary School' (Dewey, 1976, p. 318). While an advanced degree in one of the 'hard' sciences is not a requirement, a love of nature and natural history, and a commitment to working with children and their families are essential prerequisites.

Evaluation design and methods

NtN began operating as a pilot programme in one New Brunswick, New Jersey elementary school in May 2010, after 18 months of planning, partnership development and site preparation. The structure of the evaluation pilot was approved and processed by the Rutgers

University Institutional Review Board (IRB) in February 2010 under Protocol #09–223mc. A random sample of 24 students, stratified by gender, as well as a waiting list of 12 students was drawn from the 65 students who comprised the third-grade class. All students not selected for NtN or the waiting list were placed in a control group. The parents of the prospective NtN children were asked by the school principal and the NtN co-directors to sign a consent form memorialising their permission to allow their children to participate in the set of learning opportunities and activities identified as NtN. Eighteen parents returned signed consent forms, three could not be located, and three refused. The reasons given for refusal were an impending move from the school or school district, or a potential conflict with another programme.

The consent form outlined (in English and in Spanish) the educational goals that NtN was seeking to accomplish, namely (1) increase their child's performance in science and maths, (2) promote positive health and nutrition behaviour, (3) increase problem-solving skills, (4) enhance their child's communication and social skills, (5) encourage a deep appreciation of nature and the environment, and (6) provide a venue for parental and neighbourhood engagement in the education process. The consent process also made parents aware of NtN's basic architecture as both a two-day, 6 h per week after-school programme and a three-day, 6.5 h per day summer programme that would continue from fourth to the end of eighth grade.

As noted, NtN employs a classical experimental design to measure the impact of the programme. Experiments have the useful quality of controlling for both measured and unmeasured factors that could, in addition to the NtN intervention, be responsible for changes in knowledge, attitudes, or behaviours. NtN and control students are assessed at the beginning of the academic year on a series of academic, attitudinal or behavioural measures gleaned from school administrative databases, report cards and student surveys. Data on these measures are again collected at the end of the school year. Inasmuch as random assignment helps to promote equivalence between groups at baseline, any differences in outcomes can be unambiguously attributed to NtN, barring threats to internal validity such as differential attrition, interfering treatments or treatment contamination. It would be difficult to overstate the importance that the idea of a strong evaluation design had on the decision of school officials to adopt NtN.

In Table 1, we provide profiles of the NtN and Control group students at baseline, i.e. at graduation from third grade and before entering the NtN summer programme as fourth graders in 2010.

It is clear from the table that random assignment appears to be successful in creating an equivalence between NtN and control students on the measured characteristics of race, poverty (school lunch programme), English as primary language at home, and average grades in maths, language arts and science. The difference in gender proportions is attributable to the gender stratification process mentioned earlier. In one respect, i.e. the percentage of students living in two-parent families, the random assignment proved insufficient in yielding equivalent groups. While approximately 67% of control students lived with two parents according to the school's database, only 44% of NtN students had this living arrangement. A large literature has reported that single-parent families face substantially more challenges than do two-parent families in providing high-quality education, health and economic benefits to children (Choi & Jackson, 2011; Ellwood & Jencks, 2004; McLanahan & Booth, 1989). This baseline difference would appear to indicate that the NtN students in this pilot study have fewer home resources, on average, than other third graders.

Table 1. Characteristics of NtN and control-group samples at baseline academic year 2009–2010.

Characteristics	NtN group	Control group
Percentage female	55.6	38.5
Grade level	3	3
Age	8.2	8.3
Race		
Percentage Hispanic	77.8	71.8
Percentage Black	16.7	25.6
Percentage Asian	5.6	0
Percentage receiving free or reduced lunch	100.0	97.4
Percentage living with two parents*	44.4	66.7
Percentage speaking English at home	27.8	28.2
Average days absent	4.9	8.3
Average grade in:		
Maths	80.1	79.5
Language Arts	79.5	76.9
Science	81.4	79.3
Number of students	18	39

Note: *Indicates statistically significant difference at $p < 0.1$.

Although sample cases appear to be assigned randomly in the NtN pilot, estimates of treatment impact remain subject to internal validity considerations. One threat to validity could arise from the attrition of cases from the experiment, affecting both NtN and control group students. Movement of households in disadvantaged communities is a way of life as parents search for better housing, better schools and improved job opportunities. The NtN and control samples were not exempt from this mobility dynamic with NtN losing six students over the four-year study period and the control group bearing a 13-student loss.

We follow the typical analytic strategy for experimental data, testing for equality of means and variances and reporting statistical significance. Alpha levels were set at 0.1 to acknowledge the pilot nature of the study and small sample sizes; 90% confidence reduces the likelihood of accepting the null hypothesis under these conditions. It should be noted that the group comparisons were made independently for each year of the treatment and this approach to analysis could be seen as a limitation if the NtN effect varies over time. While the analysis of pooled, yearly data would allow the modelling of time and increase the experiment's power, pooling over the four years provides an estimate of treatment impact that obscures the grade-specific effects essential to gain a more thorough understanding of a pilot programme's dynamics.

Results

Table 2 shows results from four years of NtN and control group comparisons on four academic measures, namely mathematics, language arts, science grades, and average days of absence. All these data were gleaned from the school's administrative database. The table also contains a series of demographic factors to provide the reader with context when examining the time path of any NtN effects. The focus in the table is on significant post-period comparisons between NtN and control group students; significant pre-post and baseline-post comparisons within the NtN group are not reported inasmuch as these changes may reflect not only NtN impact but general child development as well, and also confound NtN impact with age- and grade-specific curriculum content and learning.

We see that NtN students achieve better science grades than their control counterparts in all four years of the pilot; in two of these years the differences are statistically significant. NtN students also perform better than controls in language arts in three out of the four study years; and in this instance two of the three differences in grades are statistically significant. NtN students have higher mathematics grades than controls; however, the difference never reaches statistical significance.

In an effort to identify the possible effects of 'underpowered treatment', comparisons between high-attendance NtN students and controls were made, and these results are displayed in Table 3. High-attendance students are defined here as individuals who attended at least 70% of after-school and summer programme classes in an academic year. We see that NtN students have significantly lower levels of school absences than do controls, a pattern also evident in Table 2. With respect to grades, the overall pattern of effects in the table is not very different from that shown in the previous table. Differences, however, do tend to be a bit larger in Table 3, suggesting that socio-cultural factors that affect levels of parental involvement and student commitment may be at play here.

Table 2. The four-year academic outcomes of NtN and control groups' student samples.

	Post (2010–2011)		Post (2011–2012)		Post (2012–2013)		Post (2013–2014)	
Characteristic	NtN	Control group	NtN	Control group	NtN	Control group	NtN	Control group
Percentage Female	55.6	38.5	62.5	37.14	68.75	56.0	66.7	56.5
Grade Level	4	4	5	5	6	6	7	7
Race								
Percentage Hispanic	77.8	71.8	75.0	80.0	75.0	73.0	80.0	82.6
Percentage Black	16.7	25.6	16.7	25.6	12.5	24.5	13.3	17.4
Percentage Asian	5.6	0	6.25	0	6.3	0	6.7	0
Percentage receiving free or reduced lunch	83.3	92.1	87.5	93.43	87.5	95.5	100.0	100.0
Percentage speaking English at home	27.8	28.2	31.25	20.0	32.2	21.1	33.3	26.1
Average days absent	4.8*	7.5	2.85*	6.22	6.0*	9.2	7.5	9.7
Average grade in:								
Maths	83.2	81.6	82.9	80.9	72.9	70.0	75.1	71.5
Language Arts	77.6	79.6	82.8*	78.8	78.9	76.0	79.4*	73.3
Science	83.6	82.9	83.5	82.0	81.3*	74.8	78.4*	73.2
Number of Students	17	34	16	35	16	30	15	25

Note: *Indicates statistically significant difference at $p < 0.1$.

Table 3. Comparisons between high-attendance NtN students and control group students on academic outcomes.

	Post (2010–2011)		Post (2011–2012)		Post (2012–2013)		Post (2013–2014)	
Academic outcome	NtN	Control group	NtN	Control group	NtN	Control group	NtN	Control group
Average grade in:								
Maths	83.4	81.6	82.9	80.9	74.2	70.0	76.2	71.5
Language Arts	82.3	79.6	82.8*	78.8	80.0	76.0	81.4*	73.3
Science	84.0	82.9	83.5	82.0	81.6*	74.8	80.2*	73.2
Average Days absent	4.5*	7.5	2.85*	6.22	5.5*	11.2	7.0	9.7
Number of Students	15	34	14	35	13	30	13	25

Note: *Indicates statistically significant difference at $p < 0.1$.

Table 4. Summary of science knowledge assessment for NtN and control group students.**

	Post (2009–2010)	Post (2010–2011)	Post (2011–2012)	Post (2012–2013)
All NtN students				
Percentage of correct answers	29.6 (1)	55.4 (1)	51.7 (2) *	36.3 (2)
Number of students	18	18	16	13++
High-attendance NtN students				
Percentage of correct answers	–	57.8	50.8	36.2
Number of students	–	15	14	11++
Control students				
Percentage of correct answers	32.3	51.1	39.3	32.8
Number of students	33	34	35	30

Notes: **Assessment was not administered in academic year 2013–2014.
(1) Scores based on 47 items.
(2) Scores based on 42 items.
*Indicates statistically significant difference at $p < 0.1$.
++Three students did not complete the assessment.

Table 5. Four-year impacts of NtN students' academic performance.*

	Year 1	Year 2	Year 3	Year 4
	(2010–2011)	(2011–2012)	(2012–2013)	(2013–2014)
	Difference	Difference	Difference	Difference
	(NtN–Control)	(NtN–Control)	(NtN–Control)	(NtN–Control)
Average grade in:				
Maths	0.0	+2.0	+2.9	+3.6
Language arts	−3.2	+4.0*	+2.9	+6.1*
Science	+ 2.5	+1.5	+6.5*	+5.2*
Student assessment	+4.3	+11.4*	+3.5	N/A

Note: *Indicates statistically significant difference at $p < 0.1$.

In Table 4 we show results from the year-end assessment used to gauge students' knowledge of nature and science. The assessment also attempts to gauge changes in students' observational skills. Each year's assessment, which averaged about 45 items, was given to both NtN and control group students by the school's science teachers. Each year's assessment contained a small set of questions that were repeated over the study period along with questions specific to the science content taught in the particular grade.

Table 4 reveals that although control students did better on the assessment than NtN students at the beginning of the fourth grade, NtN students did better than controls at the end of the fifth, sixth, and seventh grades. The drop in average percentage of correct answers in academic year 2012–2013 reflects, in part, the sixth grade's focus on physics and an NtN curriculum that remained centred on natural science, biology, environmental science, and chemistry. A summary of NtN academic effects is presented in Table 5. The NtN intervention is responsible for consistent impact on academic performance over the four-year pilot.

Discussion and conclusions

The problem of poor academic performance among children from disadvantaged families, especially black and Hispanic children living in poverty, continues to be a national tragedy. Inadequate academic preparation at the elementary (aged 7–12) and middle school (aged

13–14) levels increases the likelihood that these children will have difficulties in high school and, if they graduate, in higher education and in the labour market. Failure in science and maths courses, moreover, are almost certain to eliminate students from high-paying jobs in STEM and in the health professions. Complicating matters even more is the evidence that as hard, technical skill acquisition freezes or erodes, so do soft skills and the social capital equally necessary for career success (see, for example, Heckman, 2013; Heckman & Masterov, 2008).

The principal remedies employed to close the educational gap between more privileged and disadvantaged students in science and mathematics have resulted in some small successes and many more efforts that have either failed or proved to be inconclusive. A science-enriched curriculum, science and maths focused after-school programmes and summer learning loss prevention are amelioratives with enthusiastic proponents, some of whom have claimed indubitable successes. Careful evaluations of these interventions, especially those using experimental or strong quasi-experimental designs, tell a different story and one that is not so positive.

The generally lacklustre showing of interventions designed to close the achievement gap may simply be, as some researchers have pointed out (Blair, 2009; McCombs et al., 2011; Somers et al., 2015), the problem of underpowered treatments, i.e. the results from short treatment schedules, poor attendance by participants, fragmented/poor implementation, and uninvolved parents. While we believe that such critiques have considerable merit, we also do not believe they tell the whole story. We believe it is critical that science programmes for youth, and especially disadvantaged youth, connect children at a young age to the beauty, wonder and, indeed, the magnificence of the natural world. As Sund and Lysgaard (2013), Esbjorn-Hargens and Zimmerman (2009) have observed, environmental science and sustainability teaching has largely become disaffected from individual inquisitiveness, personal interest and place. Bonnett (2013) makes a similar point when he avers that science education has become a vehicle for 'normalizing catastrophe'.

In this study we set out to answer two research questions: namely, can a natural science based programme of teaching and student engagement (1) increase elementary school performance in science and mathematics, and (2) increase student knowledge of nature. We find some positive evidence to support both of these hypotheses. Some of the preliminary success of NtN reported in this paper can be attributed to a clear philosophy of education that can be traced to the seminal work of John Dewey, and to the integration of eight components that have been identified as critical in the literature on science and mathematics performance: (1) small class size, (2) individualised tutoring, (3) high-quality instruction, (4) after-school and summer programmes aligned with the school curriculum, (5) high levels of student attendance and participation, (6) involved parents, (7) hands-on learning opportunities in environmental and natural sciences, and (8) an intervention of sufficient duration to insure maximum dosage (see, for example, McCombs et al., Levine & Zimmerman, 2010; Tough, 2013). Another reason for this success, however, emanates from a conscious effort to teach science and mathematics as an extension of ecological intelligence. Not only does NtN go beyond the definition of learning as primarily book learning (Dewey, 1976; Whitehead, 1929) and now electronic learning, but the programme, in the words of David Orr, attempts to 'teach things the earth would teach us: silence, humility, holiness, connectedness, courtesy, beauty…' (p. 52). The academic performance of students, so highly valued by school administrators and parents, would appear to benefit within this type of environment even as the students' appreciation for the wonders of nature flourishes.

This study possesses the limitations found in most pilots, i.e. small sample(s) and limited intervention sites, the issues that accompany a first-time implementation. The use of a successfully implemented, experimental design, however, helps to minimise the internal validity and generalisability issues found in the many pre-post and post-test only evaluations.

Nurture thru Nature marks an attempt to consciously bring to life the University Elementary School described by John Dewey (1976, p. 92) starting with elementary school children's personal interests in nature and introducing deeper learning sequences, specialised topics and abstract topics from year to year. Drawing on John Dewey's Middle Works (1976), NtN's strategic vision recognises that children are never passive recipients of education but rather are actively engaged agents in their own life's dramas. Moreover, there is a recognition that young students 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 students' interests and habits derive from their homes and neighbourhoods (Dewey, 1976, p. 30). Pulling additionally from Dewey's later writings (1990) there is a tacit recognition in this vision that true learning is not simply the acquisition of what others know but is more akin to the development of capital that can be used 'to create an eager alertness in observing and judging the conditions under which one lives' (Dewey, 1990, p. 463). When discussing the programme with public school officials, the designers of NtN made the case that the melding of active learning and a natural history philosophy would very likely have a positive impact on student grades.

NtN is subject to the many challenges that characterise the day-to-day living of students in United States urban centres, challenges that were all but impossible to imagine a century ago or even 50 years ago. Transporting young students into a world of exploration and wonder from one of poverty, crime, electronic distraction and constant household mobility will require help from all sectors of society – universities and businesses as well as public schools and families.

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