# Refueling Students in Flight: Lessons in Nature May Boost Subsequent Classroom Engagement

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## 1 Introduction

When teachers offer lessons in relatively natural settings, students may benefit in a number of important ways. Academically, some evidence suggests students retain more after lessons in nature in biology and math (Fägerstam & Blom, 2012), language arts, social studies, and science more generally (Lieberman & Hoody, 1998) than after similar lessons indoors. Lessons in nature may also offer other benefits associated with exposure to trees, gardens, parks, and wildlife, including physical activity, stress relief, and the rejuvenation of attention (for reviews see Chawla, 2015; Kuo, 2015; see also Ming, Banres & Jordan: Do Experiences with Nature Promote Learning? Converging Evidence of a Cause-And-Effect Relationship and Chawla: Childhood Nature Connection and Constructive Hope in this volume). Furthermore, as anthropogenic climate change becomes an increasingly pressing issue, lessons in nature



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may help build the next generation of environmental stewards; positive childhood nature experiences appear to play a key role in fostering pro-environmental behavior in adulthood (Monroe, 2003). Perhaps in response to these important potential benefits, many European countries are incorporating lessons in nature in their formal schooling (Bentsen & Jensen, 2012).

In the U.S. by contrast, there has been relatively little embrace of outdoor formal instruction beyond the preschool setting (Ernst & Tornabene, 2012). One reason lessons in nature have not caught on in the U.S. may be a concern on the part of teachers that outdoor lessons will leave students keyed up and unable to concentrate. In the pressure to meet achievement standards, instructors may view even temporary losses in classroom engagement as unacceptable. Classroom engagement—the extent to which students are on-task and paying attention to the material or activity at hand—is a major driver of learning and academic success (Godwin et al., 2016) and is easily disrupted. If lessons in nature do leave students 'keyed up' and unable to focus afterwards, then the benefits of that time might be outweighed by the costs.

Do lessons in nature impair subsequent classroom engagement? Our review of the environmental psychology literature suggests quite the opposite. Although we found no studies directly addressing this question, the indirect evidence suggests that classroom engagement will be enhanced, not impaired, immediately after lessons in nature. Specifically, spending time in relatively natural outdoor settings has a number of positive, immediate aftereffects on individuals, each of which is likely to enhance classroom engagement. Moreover, multiple studies have found that schools with greener, more vegetated surroundings perform better academically—even when socioeconomic factors are accounted for (Browning & Locke, 2020; Kuo et al., 2018, 2020). Here we review the evidence on acute doses of contact with nature and their effects on cognitive functioning, interest in learning, and stress, as well as the literature tying greener schools to greater academic achievement.

The capacity to pay attention is an important resource in student engagement (Pekrun & Linnenbrink-Garcia, 2012). Acute doses of nature, whether through a window view of a tree-lined street or a walk in a park, have positive aftereffects on attention and working memory. Attention restoration theory suggests that natural landscapes are gently engaging, inducing a state of "soft fascination" that allows the mental muscle underlying our ability to deliberately direct attention to rest. Afterwards, our capacity to direct attention is thereby refreshed (Kaplan, 1995; for reviews of empirical work on attention restoration theory, see Ohly et al., 2016; Stevenson et al., 2018). Experimental work has demonstrated these aftereffects for classroom window views of greenery vs. barren schoolyards (Li & Sullivan, 2016), and for walks in both forested (van den Berg et al., 2017) and relatively green urban settings (Faber Taylor et al., 2001) as compared to walks in less green urban settings. Thus, both a lesson in a relatively green spot in a schoolyard and the walks between that spot and the classroom might rejuvenate students' attention, enhancing their ability to concentrate on the next, indoor lesson.

Motivation is another important factor in student engagement (Deci et al., 2011), and nature-based learning has been tied to high levels of engagement and enjoyment in several studies. Although we found no studies examining aftereffects of acute doses of nature, children prefer and enjoy lessons outdoors over lessons indoors (Mygind, 2009; Wistoft, 2013), and there is some indication that outdoor nature-based learning fosters greater interest in school and learning generally (e.g., Ernst & Stanek, 2006). Importantly, these effects may be largest in precisely the students whose motivation in 'normal' classes is most lacking (Dettweiler et al., 2015). Nature-based learning appears to foster students' intrinsic motivation (Bølling et al., 2018; Fägerstam & Blom, 2012; Skinner et al., 2012). Collectively, this body of work suggests nature-based instruction makes learning more interesting and enjoyable. Might the interest and positive affect from a lesson in nature carry over to the next, indoor lesson, resulting in greater classroom engagement?

Stress is likely to be an important, negative, factor in student engagement; high levels of stress consistently predict lower levels of academic achievement (e.g., Grannis, 1992; Leppink et al., 2016). Experimental work in adults with physiological indicators shows that contact with nature offers quick and powerful reductions in stress biomarkers (e.g., Park et al., 2010; for review, see Kuo, 2015; Supplementary Materials), and this effect appears to extend to children as well. Contact with nature has been tied to lower levels of both self-reported and physiological measures of stress in multiple studies with children (Bell & Dyment, 2008; Chawla, 2015; Wiens et al., 2016). Recently an experimental study involving high school students showed that even a mere window view of vegetation from a classroom yields systematic decreases in both heart rate and self-reported stress, whereas a classroom without such views does not (Li & Sullivan, 2016). Further, students learning in a forest setting one day a week showed healthier diurnal rhythms in the stress hormone cortisol in that setting than a comparison group that did not receive outdoor learning—and these effects could not be attributed to the physical activity associated with learning outdoors (Dettweiler et al., 2017).

Not only is contact with nature tied to important factors in classroom engagement, but greener schools and classrooms have been tied to better academic achievement. Multi-year assessments of greenness around Massachusetts public schools found positive correlations between greenness and standardized test scores, even after adjusting for income and other confounding factors, although not for all seasons of the year (Wu et al., 2014). Similarly, standardized test performance of 3rd through 9th graders was higher in District of Columbia public schoolyards with higher levels of tree cover, again after adjusting for income and other factors (Kweon et al., 2017), and high school graduation rates and test scores were better for public high schools across Michigan with classroom and cafeteria views of greenspace (Matsuoka, 2010). More recently, standardized test scores have been tied to schoolyard tree cover in over 300 public schools in Chicago, again controlling for socioeconomic and other factors (Kuo et al., 2018). While these studies do not directly connect nature exposure with increased classroom engagement, they are consistent with this possibility. Indeed, it is difficult to imagine how contact with nature could boost academic achievement while reducing classroom engagement.

Thus, exposure to nature has been tied to both the antecedents and consequences of classroom engagement—the factors contributing to, and outcomes of, greater classroom engagement. Additional converging evidence comes from research in educational psychology not focused specifically on greenness. Generally speaking, time spent out of the classroom and in relatively natural outdoor settings is positive. Studies document (a) the rejuvenating effects of recess (e.g., Jarrett et al., 1998; Pellegrini & Davis, 1993; Pellegrini et al., 1995), (b) the positive impacts of students' physical activity—often in schoolyards—on on-task behavior and executive functioning in the classroom (Kvalø et al., 2017; Mahar, 2011), and (c) the motivational benefits of teacher-led education outside the classroom (EOtC)—in schoolyards, museums, and other cultural institutions (Dettweiler et al., 2015; for review see Becker et al., 2017) and of garden-based learning (Skinner et al., 2012). All these lines of investigation lend indirect support for the hypothesis that lessons in nature might enhance subsequent classroom engagement.

At the same time, it must be acknowledged that the question here differs importantly from those lines of investigation. This study differs from the research on the benefits of recess and physical activity in that the intervention involves formal instruction—teacher-led, formal lessons, delivered as part of a larger curriculum, with all the rules against student socializing and autonomous activity typical of classroom-based lessons. Similarly, unlike most education outside the classroom (EOtC) studies and the study of garden-based learning, this study holds pedagogical approach constant in comparing lessons in nature vs. in the classroom. That is, in most EOtC studies, the instruction outside the classroom is designed to take advantage of the setting; as a consequence, the experimental condition differs from the control in two ways—in setting (outside vs. in the classroom) and in pedagogical approach. In this study, pedagogical approach was held constant across conditions; the lessons inside and outside the classroom differed in setting but not instructional approach.

In sum, although it appears no study has directly examined the aftereffects of lessons in nature on classroom engagement, considerable evidence in both environmental psychology and education research points to time spent in natural outdoor settings as having positive impacts. In this study, we hypothesize that *lessons in nature have positive, immediate aftereffects on classroom engagement*—that is, we expect that when children learn outdoors, their classroom engagement after returning indoors is better than it would have been had they stayed inside the entire time. To test this hypothesis, we compared classroom engagement after a teacher gave her students a lesson in nature vs. after the same teacher gave her students a lesson on the same topic in the classroom (e.g., leaves) in the same week, replicating this comparison across 10 different topics (one topic per week), two classrooms ("classroom a," with its own teacher, students, and room; and "classroom b," with another teacher, set of students, and room), and five different measures of classroom engagement.

# 2 Methods

## 2.1 *Setting and Instructors*

The effects of lessons in nature on subsequent classroom engagement were examined in the context of a 300-student environmental magnet school in the Midwestern United States serving a predominantly disadvantaged population, with 87% qualifying for free or reduced lunch, 82% African American, 7% Hispanic, 5% White, and 6% Multi-racial. Written consent from parents of involved students was obtained prior to the study.

The indoor condition in this study comprised two typical classrooms (Fig. 1; although they are not shown in the photo, both classrooms had windows). The outdoor


**Fig. 1** The two classrooms (**a**, **b**) used for indoor instruction in this study. Written permission for the publication of this figure was obtained from students' parents

condition comprised a small grassy area just outside the school (Fig. 2). This instructional area was adjacent to a stream and woodlands, neither of which were used in the lesson. While the teacher was setting up the outdoor lesson, students occasionally visited the stream bank briefly. The post-treatment (and post-control) observation period was always conducted indoors, in each class' and teacher's regular classroom.

The two teachers in this study were highly experienced and state-certified in elementary education, with Masters in Education degrees and in-service training in outdoor and environmental education. These teachers had teamed together in lesson planning over a period of 5 years prior to this study, facilitating their coordination of lessons during this study.

The students in the classrooms were in third grade. Their age range was 9–10 years old.

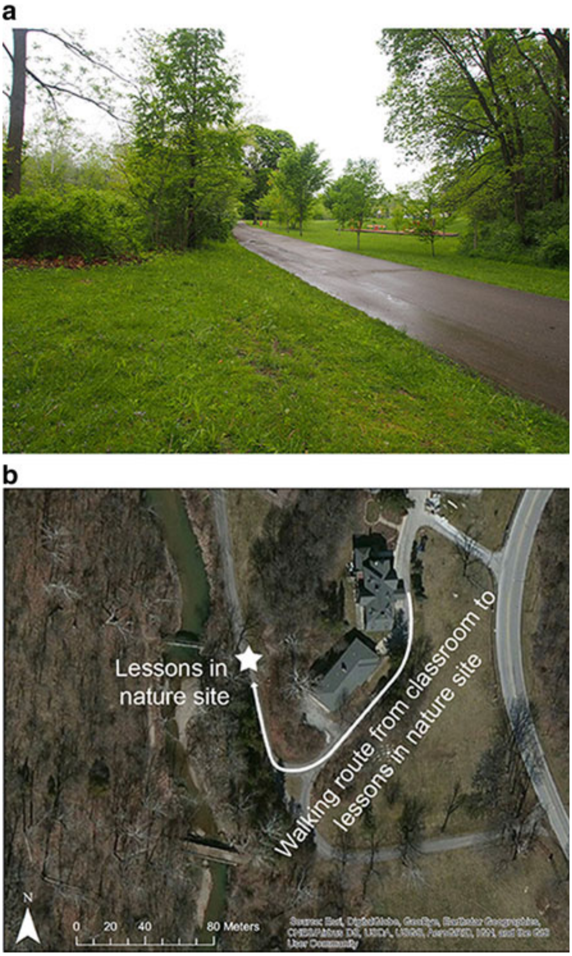


**Fig. 2** The site of the lessons in nature (**a**) and the route students took between their classroom and the outdoor lessons (**b**). The road in the pictures was used exclusively for pedestrian traffic and (infrequently) for maintenance vehicles

## 2.2 Design and Procedure

At base, this study involved a mini-experiment replicated 20 times. In each mini-experiment, we examined classroom engagement after a lesson in nature vs. after a matched lesson in the classroom on the same topic, with the same teacher and students. Thus, in week 1 of our study, teacher "a" gave her students both a lesson on, say, leaf identification, outdoors, and another lesson on leaf identification in the classroom, and we compared indoor classroom engagement for that set of students after each of those two lessons. This mini-experiment was repeated across 10 different lesson topics and weeks (one topic per week), in each of the two classrooms.

Figure 3 schematically depicts a mini-experiment—the fundamental unit of comparison in this study. Both the experimental condition (the lesson in nature) and the control condition (the lesson in the classroom) were 40 min long, and the observation period for both conditions was 20 min long. Observation periods took place in the teacher's regular classroom, and included an introductory 5-min presentation by the teacher on math or language arts using a dry erase board, overhead projector, or chalkboard and 15 min of assigned individual student work completed at their desks. Before the observation period there was a water and bathroom break in both conditions.

Figure 4 shows how we replicated our fundamental unit of comparison across different instructional content, times in the school year, students, classrooms, and instructors. Each pair of lessons (one in nature, one in the classroom) was delivered in a single week. For each pair, the two teachers worked together to adapt a different theme from the Project Learning Tree (https://www.plt.org/, accessed 28/07/2021) environmental education lesson guide, with lessons on leaf, tree, and seed identification; organic matter decomposition; lifecycles; and pollution. These two instructors each delivered 10 pairs of lessons over 10 different weeks in the semester from

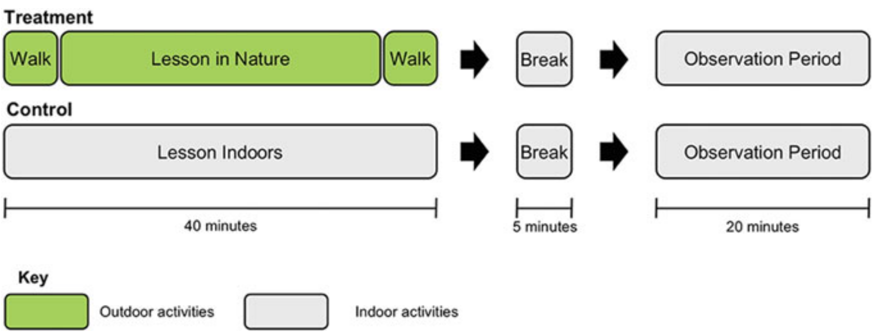


**Fig. 3** Schematic diagram of a single mini-experiment. Each mini-experiment included a treatment (lesson in nature and with walks to lesson site before and after) or a control (classroom lesson indoors), followed by a 5-min indoor break and 20-min indoor observation period. Order of conditions was counterbalanced

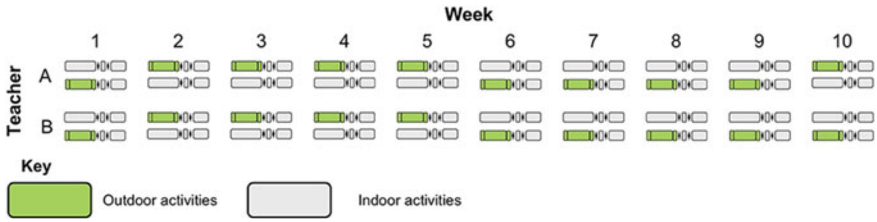


**Fig. 4** Schematic diagram of all 20 mini-experiments in this study. Mini-experiments were replicated over 10 different topics and weeks, for each of two classrooms (and each of five measures). Order of conditions was counterbalanced

September–November, under a range of weather conditions.[1] Before the study began, both instructors were open-minded as to what we might find, although one tended to think the positive effects of lessons in nature might outweigh the negative, whereas the other tended to think the opposite—that lessons in nature might leave students "too wired" afterward to engage in classroom material.

Lessons were matched along the following dimensions: teacher, students and class size, topic, teaching style, week of the semester, and time of day. That is, for any given pair of lessons, both the treatment lesson (in nature) and its indoor counterpart were delivered by the same teacher to the same students, on the same topic, in the same week of the semester. Both lessons involved hands-on, experiential learning; lessons that required natural materials from the outdoor instructional site (e.g., different types of leaves) were adapted for classroom instruction by bringing these materials indoors prior to the lesson. While the pairs of lessons were offered in afternoons ($n = 12$) slightly more often than in mornings ($n = 8$), the two conditions did not differ in how often they were taught in the morning vs. the afternoon—an important consideration, given that cognitive performance generally drops over the course of the day (Sievertsen et al., 2016).

We counterbalanced the order in which conditions were delivered each week over the course of the study. It is impossible to offer both a lesson in nature and its matched classroom lesson simultaneously; thus one lesson would have to precede the other and the second lesson would always be an extension of the first. So that neither condition would have an advantage over the other, we encouraged teachers to put the lesson in nature first roughly as often as they put it second. The scheduling of lessons was constrained by the scheduling of other curriculum (e.g., physical education, art, and music) as well as weather. In the end, the lesson in nature came before its classroom counterpart four times and after it six times for each teacher.

It is important to note that there was one consistent difference between the experimental and control lessons other than setting. The 40-min lesson in nature was not purely instructional time; it required the class to walk a few minutes to and from a

[1] On one occasion, a planned lesson was not given as scheduled; that lesson was made up in April instead. Analyses with and without the makeup lesson and its paired classroom lesson show the same effects of lessons in nature on subsequent classroom engagement. Findings reported here were based on the full sample.

grassy area (see Setting above) to reach the instructional site—a distance of about 200 m. Thus, the lesson delivered in nature was roughly 30 min long whereas the matched indoor lesson was 40 min long.

## *2.3 Measures of Classroom Engagement*

We developed a battery of four measures to assess classroom engagement: (1) teacher ratings; (2) student ratings; (3) 'redirects'—the number of times instructors had to interrupt instruction to redirect a student's attention to the task at-hand; and (4) independent photo ratings—ratings of classroom engagement by an independent observer based on photographs of the observation period. These four measures were then combined into a Composite Index of Classroom Engagement.

### 2.3.1 Teacher Ratings

At the end of each 20-min observation period, teachers rated classroom engagement on a $-2$ to $+2$ scale (from $-2$ *much worse than usual* to 2 *much better than usual*, with 0 *same as usual*). Classroom engagement was defined for teachers as students listening to instructions, looking at assigned material, and raising their hands for assistance. Teachers were asked to rate the engagement not of individual students, but of the classroom as a whole, during the observation period.

### 2.3.2 Student Ratings

Students also rated classroom engagement after each 20-min observation period. Unlike the teacher ratings, the student ratings consisted of three components. Each student rated their own engagement, the engagement of the students sitting close to them, and the engagement of the class as a whole on a 5-point scale indicating the period of engagement (from 1 *no time* to 5 *the whole time*).

Of the three types of engagement ratings—self, peer, and whole class—one turned out to be relatively uninformative and was not further analyzed: students consistently rated their own engagement at ceiling—5 out of 5 possible points, with little variance; perhaps as a consequence, this rating correlated relatively weakly with other measures. Students' ratings of the engagement of their seatmates and the class as a whole were somewhat informative in that they were not at ceiling and showed some variance; students' peer and whole class ratings were therefore used as another measure of classroom engagement. For each classroom after a given lesson, students' peer engagement ratings and whole class engagement ratings were averaged to produce a student-based measure of classroom engagement. This measure of classroom engagement demonstrated high internal reliability (Cronbach's alpha

= 0.869 for indoor lessons, 0.807 for outdoor lessons[2]); that is, different students rated engagement during a given observation period similarly.

### 2.3.3 'Redirects'

Each time a teacher needed to stop instruction to redirect or correct student behavior—e.g., "sit down," "you need to be working," or "I will wait"—one 'redirect' was tallied. 'Redirects' reflect the number of instances tallied for a 20-min observation period. Redirects are a concrete and important indicator of how well instruction is going. High levels of redirects indicate students are not attentive to instruction or tasks assigned. Further, redirects themselves are likely to impact learning outcomes by reducing the coherence and flow of lectures and distracting students as they work on assigned tasks.

MP, an investigator on this project and the social worker for the school where this study was conducted, was stationed at the back of the classroom during observation periods to record 'redirects.' Because MP was the school social worker, the instructors and students in this study were familiar with him and comfortable with his presence in the classroom. Pilot testing confirmed that he was able to observe the class from the back of the room without influencing class dynamics. Redirects were tallied "blind to condition"—that is, the observer assessed redirects without knowing whether the preceding lesson had been given indoors or outdoors.

### 2.3.4 Independent Photo Ratings

While teacher ratings and student ratings each provide a valuable window onto class engagement, both are inevitably subject to observer expectancy effects. That is, both teacher and student ratings of classroom engagement during a given observation period might be influenced by their knowledge of which condition (lesson in nature or lesson in the classroom) preceded that observation period and their expectations for the effects of lessons in nature on classroom engagement. Redirects were blind to condition, but we included a second "blind to condition" measure of classroom engagement, in which an independent observer rated photographs of each observation period without knowing what kind of lesson had preceded it.

Photographs were captured with a wide-angled camera (Nikon P90) positioned on a tripod in front of the classroom and programmed to automatically capture images of the class at even, pre-set time intervals throughout the 20-min observation period. Each observation period was represented by 10 photos; hence the complete collection of photos rated by our independent observer consisted of 400 photos, with each set of 10 photos corresponding to one of the 40 observation periods in this study (one observation period per week after the lesson in nature, another observation period

[2] Cronbach's alpha is a measure of scale reliability. It measures how closely related a set of items are as a group. It can take values between 0 and 1, and 0.7 or higher is considered 'acceptable'.

per week after its classroom-based counterpart, for each of two teachers, for a total of 10 weeks).

Our independent observer—an undergraduate student at the University of Illinois at Urbana-Champaign—began by acquainting herself with the entire collection of 400 photos, without knowing which observation periods belonged to which condition. This allowed her to calibrate her ratings of classroom engagement relative to both the typical levels of engagement seen in the observation periods as well as the extremes. She then rated classroom engagement for each observation period on the same −2 to +2 scale as the teachers (from −2 *much worse than usual* to 2 *much better than usual*, with 0 *same as usual*). The rater assessed classroom engagement blind to condition; that is, she made her ratings without knowing where the preceding lesson had taken place (in nature vs. the classroom).

### 2.3.5 Constructing a Composite Index of Classroom Engagement (CICE)

Each of the component measures in our battery is valuable in its own right. Teacher ratings and student ratings offer important lenses on classroom engagement. Redirects, as counted by an independent observer, provide external validation for teacher and student-ratings as well as a concrete measure of classroom engagement. Both redirects and the independent photo ratings provide measures of classroom engagement uncontaminated by knowledge of condition. Table 1 illustrates how each of

**Table 1** Measures and criteria for assessing classroom engagement

| Measure | CRITERIA FOR ASSESSING CLASSROOM ENGAGEMENT | | | |
|---|---|---|---|---|
| | Incorporates teacher perceptions | Incorporates student perceptions | Provides external validation | Is blind to condition |
| Teacher ratings | Yes | – | – | – |
| Student ratings | – | Yes | – | – |
| Redirects | – | – | Yes | Yes |
| Independent photo ratings | – | – | – | Yes |
| Composite index of classroom engagement | Yes | Yes | Yes | Moderately[a] |

[a] *Two of four components of Index are blind to condition.*

the measures in our battery address different methodological criteria for assessing classroom engagement. Together, the measures in this battery provide a multifaceted assessment of classroom engagement, with the limitations of each measure countered by the strengths of another.

To create a single, summary measure that draws on each of these different methodological strengths, we combined the component measures into a single Composite Index of Classroom Engagement (CICE)—the average of teacher ratings, student ratings, independent photo ratings, and redirects. Because these measures are on different scales (e.g., from −2 to +2 for teacher and photo-based ratings, from 0 to 100 for student ratings), data from each measure were standardized before averaging. Thus, for example, a teacher's rating of classroom engagement for a given observation period would be expressed in terms of how that period's rating differed from the mean rating for that teacher across all observation periods, in units of standard deviations. Redirects were reverse-coded (multiplied by −1.0) so that higher values would correspond to better classroom engagement, in line with the other components of the Composite Index.

# 3 Results

## *3.1 Descriptive Statistics and Bivariate Correlations*

Descriptive statistics and bivariate correlations across all observation periods (that is, regardless of whether they occurred after an indoor or outdoor lesson) are presented in Tables 2 and 3. Teacher ratings of class engagement tended toward the positive, with average ratings falling between 0 *usual* and 1 *better than usual*. Student ratings of class engagement were quite positive, averaging roughly 80% on a 0–100% scale,

**Table 2** Means of classroom engagement measures by classroom

| | | Classroom A | | Classroom B | |
|---|---|---|---|---|---|
| | Range | *M* | *SD* | *M* | *SD* |
| Teacher ratings (−2–+2) | −2–2 | 0.70 | 1.34 | 0.55 | 1.23 |
| Student ratings (0–100) | 62–93 | 81.29 | 8.09 | 79.00 | 7.55 |
| Redirects (tallied) | 0–8 | 3.70 | 2.62 | 5.10 | 1.86 |
| Independent photo ratings (−2–+2) | −2–2 | 0.35 | 1.42 | 0.65 | 0.99 |
| Composite index of classroom engagement | −1.60–1.17 | 0.00 | 0.81 | 0.00 | 0.77 |

**Table 3** Bivariate correlations between measures of classroom engagement across 40 observation periods

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Teacher ratings (1) | – | 0.48** | 0.54** | 0.87** | 0.92** |
| Student ratings (2) | | – | 0.25 | 0.32* | 0.63** |
| Redirect (3) | | | – | 0.51** | 0.70** |
| Independent photo ratings (4) | | | | – | 0.86** |
| Composite index of classroom engagement (5) | | | | | – |

*$p < 0.5$, **$p < 0.01$.

with little variance. Redirects occurred with some frequency, averaging 3.7 and 5.1 in the two classrooms, respectively, in the 20-min observation window. And photo-based ratings of class engagement also tended toward the positive, with average ratings falling between 0 *usual* and 1 *better than usual*. As the CICE (Composite Index of Classroom Engagement) is based on the average of standardized scores across the four component measures for each classroom, its means for each classroom were zero by definition. In two-sided *t*-tests for group differences with an alpha of 0.05, the two classrooms did not significantly differ from each other on any of the measures of classroom engagement; thus data from the two classrooms were combined for further analysis except where otherwise noted.

As Table 3 shows, our measures of classroom engagement were generally highly correlated. The individual components of the CICE show high concurrent validity. Teacher ratings and independent photo-based ratings were particularly highly correlated with both each other ($r = 0.87$) and with our summary measure ($r = 0.92$). Student ratings of classroom engagement were significantly correlated with teacher ratings ($r = 0.48$) and independent photo-based ratings ($r = 0.32$), but not significantly related to the number of redirects in a given observation period.

## *3.2 Overall Condition Differences in Classroom Engagement*

Is classroom engagement higher after a lesson in nature than after a matched lesson in the classroom? Table 4 presents the results of paired, two-tailed *t*-tests comparing classroom engagement after lessons in nature versus matched classroom lessons across the 10 different topics/weeks and two instructors. Lessons in nature show an advantage in subsequent classroom engagement over classroom lessons for four of the five measures. Teacher ratings of classroom engagement are roughly a standard

**Table 4** Classroom engagement is better after lessons in nature than lessons in the classroom by most measures: Findings for each measure of classroom engagement

| | Means | | Paired differences | | | | |
|---|---|---|---|---|---|---|---|
| | Nature | Classroom | Mean | Std. dev. | *t*-value | df | Effect size[a] |
| Teacher ratings | 1.20 | 0.05 | 1.15 | 1.79 | 2.88** | 19 | 0.74 |
| Student ratings | 81.01 | 79.27 | 1.74 | 6.56 | 1.18 | 19 | 0.60 |
| Redirects | 3.10 | 5.70 | −2.60 | 2.62 | 4.43*** | 19 | 0.84[b] |
| Independent photo ratings | 1.10 | −0.10 | 1.20 | 1.64 | 3.27** | 19 | 0.77 |
| Composite index | 0.40 | −0.40 | 0.80 | 0.93 | 3.83** | 19 | 0.81 |

[a]*Common language effect size (McGraw and Wong, 1992) also known as the probability of superiority (Grissom and Kim, 2005) expresses the effect size in percentages. In this table, it reflects the probability that the score for a given classroom engagement measure will be better after a lesson in nature than after a lesson in a classroom. Controlling for differences between classrooms in classroom engagement, the likelihood that a class will score higher on teacher ratings of classroom engagement after a lesson in nature than after a lesson in a classroom is 74%.*

[b]*For ease of interpretation, all effect sizes reflect the likelihood of better class engagement after a lesson in nature than a matched classroom lesson; because class engagement is better when redirects are fewer, the effect size reported here reflects the likelihood that redirects are fewer after a lesson in nature.* **$p < 0.01$, ***$p < 0.001$.

deviation higher, on average, after a lesson in nature than its matched, classroom-based counterpart. Consistent with this, redirects were less frequent after a lesson in nature—in fact, the number of redirects after a lesson in nature was roughly half (54%) that of redirects after a classroom lesson. If we calculate the rate of redirects by dividing the duration of our observation period (20 min) by the number of redirects, the nature condition yielded a redirect rate of roughly one redirect per 6.5 min as compared to a rate of one interruption of instruction every 3.5 min in the classroom condition. The independent, photo-based ratings of classroom engagement echo the teacher ratings. And Composite Index of Classroom Engagement scores are 4/5ths of a standard deviation higher after lessons in nature than after matched control lessons. Effect sizes for all measures except the student ratings are substantial, indicating that the magnitude of the difference between classroom-based lessons and nature-based lessons is not only statistically significant but practically meaningful.

Bayesian statistical analyses yield similar results. The Bayes factor is a ratio of the likelihood of two hypotheses being correct given a set of data. In this case, we compared the likelihood that classroom engagement was better after outdoor lessons than after indoor lessons ($H_1$) with the likelihood that it was not better ($H_0$). There was very strong evidence that the Composite Index of Classroom Engagement was better after outdoor lessons than after indoor lessons—so much so that $H_1$ was 33 times more likely to occur than $H_0$. In regard to individual measures, redirects showed extreme evidence for $H_1$ occurring, indicating increased classroom engagement after outdoor lessons ($BF_{01} = 0.009$, error percent $8.07e^{-7}$), while independent photo-based ratings of classroom engagement displayed strong evidence ($BF_{01} = 0.091$, error percent $= 5.12e^{-4}$) and teacher ratings of classroom engagement presented moderate evidence ($BF_{01} = 0.18$, error percent $= 0.002$) for this outdoor lesson advantage. In contrast, student ratings of classroom engagement showed no evidence of nature lessons improving classroom engagement afterward compared with indoor lessons ($BF_{01} = 2.33$, error percent $= 0.014$).

### *3.3 Condition Differences in Classroom Engagement for Different Classrooms, Weeks, and Measures*

Our research design involved 100 paired comparisons between lessons in nature versus their matched, classroom-based counterparts across two different instructors, 10 different topics and weeks, and five different measures of classroom engagement. To give a more fine-grained view of our results, Fig. 5 schematically depicts the results for each of the 100 pairs of comparisons.

Figure 5 thus illustrates the consistency and size of the nature advantage over the entire series of mini-experiments. Of the 100 nature versus classroom comparisons, the majority of comparisons (61) show an advantage for the lesson in nature (i.e., check marks in the Figure), 25 show small or no difference (less than half a standard deviation in either direction, i.e., no symbol in the Figure), and only 14 show an

| | | Wk1 | Wk2 | Wk3 | Wk4 | Wk5 | Wk6 | Wk7 | Wk8 | Wk9 | Wk10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Classroom a | Teacher ratings | ✔✔✔ | ✔✔✔ | ✔✔ | | | ○○ | ✔✔ | | | ✔✔ |
| | Student ratings | ✔✔✔ | ✔✔ | ✔✔ | ○ | | | | | ○○ | |
| | Redirects | ✔ | ✔ | ✔✔✔ | ✔✔ | ✔✔✔ | ○○ | ✔✔ | ○ | ✔✔✔ | ✔✔ |
| | Independent ratings | ✔✔✔ | ✔✔✔ | ✔✔ | | | ○○○ | ✔✔ | | ✔✔ | |
| | Composite index | ✔✔✔ | ✔✔ | ✔✔ | | ✔ | ○○ | ✔✔ | | ✔ | ✔ |
| Classroom b | Teacher ratings | ○○ | ✔✔✔ | ✔✔✔ | ○○ | ✔ | ✔ | ✔✔ | ✔✔ | ✔ | ✔✔✔ |
| | Student ratings | ○ | ✔ | | ○○ | | | ✔ | | | |
| | Redirects | ○ | ✔✔✔ | | ✔✔ | ✔✔✔ | | ✔✔ | ✔✔✔ | ✔✔ | ✔✔ |
| | Independent ratings | ○ | ✔✔✔ | ✔✔✔ | | ✔ | ✔✔ | ✔✔✔ | ✔✔✔ | ✔✔ | ✔✔✔ |
| | Composite index | ○ | ✔✔ | ✔✔ | | ✔ | ✔ | ✔✔ | ✔✔ | ✔✔ | ✔✔ |

**Fig. 5** Differences in classroom engagement after lessons in nature for different classrooms, weeks, and measures. Condition differences in classroom engagement are depicted with symbols. The color and shape denotes the condition which yielded better classroom engagement, for a particular measure, classroom, and week; when the lesson in nature outperformed its paired classroom lesson, there are checkmark(s); when the lesson in the classroom outperformed its paired nature lesson, there are circle(s). The number of symbols (checkmark or circle) represents the extent to which one condition outperformed the other, with one symbol corresponding to a difference between half a standard deviation and a full standard deviation (>0.5 to 1), two symbols corresponding to a difference between one and two standard deviations (>1 to 2), and three symbols corresponding to a difference of over two standard deviations. When the difference between a lesson in nature vs. the classroom did not exceed half a standard deviation, no symbols are depicted

advantage for the classroom-based lesson (circles in the Figure). Further, the size of the nature advantage is considerable: in 48 comparisons, the lesson in nature yielded classroom engagement scores a full standard deviation larger than its classroom-based counterpart; in 20 of these 48, the nature advantage was more than two standard deviations.

When we compare the results for different measures in Fig. 5, we see that four of the component classroom engagement measures—teacher ratings, redirects, and independent (photo-based) ratings—show more, and larger condition differences (more symbols), suggesting that these measures may be more sensitive to variations in classroom engagement. By contrast, student ratings appear to be a relatively insensitive measure, showing fewer and smaller condition differences than the other measures.

Similarly, visual inspection reveals no obvious trends in the size of the nature advantage over the course of the semester. Consistent with this, a *post-hoc*, two-tailed independent *t*-test comparing the difference between CICE scores for the first 5 weeks of the semester with CICE scores for the next 5 weeks showed no significant difference, $t_{(18)} = -0.26$, $p = 0.80$ ($M = 0.86$, $SD = 1.00$ for the first 5 weeks; $M = 0.74$, $SD = 0.91$ for the next 5 weeks). Interestingly, although one of the two instructors entered with some skepticism regarding the effects of lessons in nature on subsequent classroom engagement, the nature advantage is visible in both instructors' classes. Paired, two-tailed $t$-tests for each classroom show a significant effect of condition on classroom engagement for each instructor [$t_{(9)} = 2.27$, $p = 0.049$, for classroom $a$; $t_{(9)} = 3.07$, $p = 0.01$, for classroom $b$]. Bayesian statistical analyses confirmed there was no evidence for the first 5 weeks being different than the next 5 weeks ($BF_{01} = 2.41$, error percent $= 2.31e^{-5}$). Also, Bayes factors showed moderate evidence for classroom $a$ ($BF_{01} = 0.20$, error percent $= 3.41e^{-4}$) and 'anecdotal' evidence for classroom $b$ showing an outdoor lesson advantage ($BF_{01} = 0.56$, error percent $= 0.002$).

## 4 Discussion

What is the effect of lessons in nature on subsequent classroom engagement? Do they leave pupils too keyed up to focus—as some teachers worry—or do they enhance a class' engagement—as indirect evidence has suggested they could? In this study, classroom engagement was significantly better after lessons in nature than after matched, classroom-based lessons. This nature advantage held for four of five measures of classroom engagement: teacher ratings; redirects; independent, photo-based ratings; and our summary index of classroom engagement all showed a substantial advantage for the nature condition; student ratings did not. Further, the nature advantage held across different teachers and held equally over the initial and final 5 weeks of lessons.

The nature advantage was substantial. Common language effect size calculations (McGraw & Wong, 1992) indicate a strong advantage for lessons in nature—the likelihood that Composite Index of Classroom Engagement scores are higher after a lesson outdoors in nature than after a lesson in the classroom, in a class that receives both, is 81%. And the nature advantage is large. Out of 100 paired comparisons, classroom engagement was over a full standard deviation better in the nature condition in 48 pairs; in 20 of those 48, the nature condition bested its classroom counterpart by over two standard deviations. The rate of 'redirects,' or instances where a teacher interrupted the flow of instruction to redirect students' attention, was cut almost in half after a lesson in nature. Normally, these redirects occur roughly once every 3.5 min of instruction; after a lesson in nature, classroom engagement is such that teachers are able to teach for 6.5 min, on average, without interruption.

### *4.1 Accounting for the Advantage of Lessons in Nature: Alternative Explanations*

To what might we attribute the advantage of the lessons in nature here? Any number of factors may affect classroom engagement: different teachers might be more skilled at eliciting student engagement; some topics are more engaging than others; hands-on lessons might be more engaging than lecture-based lessons; one set of students might be more attentive than another; a smaller class might be more engaged than one with more students; one classroom might be exposed to more distractions than another; engagement might peak at the beginning of the school year and flag as the year wears on; and students might find it easier to focus on schoolwork in the morning than the afternoon. If our nature lessons differed from our classroom lessons in any of these respects, those differences could have conceivably accounted for our findings. But because we only compared pairs of lessons *matched* on all those factors—same teacher, same topic, same instructional approach, etc.—none of those factors can account for the findings here.

Nor could positive expectations have entirely driven the nature advantage here. It is true that one of the two teachers expected the lesson in nature might have a positive effect on subsequent classroom engagement. Those positive expectations might have led her to view classroom engagement after the outdoor lesson more positively (which might have boosted teacher ratings of engagement but would not have affected our independent photo-based ratings), or might even, in a variant of the Pygmalion effect, have inspired her to teach more effectively afterwards (which would have boosted both teacher ratings and independent photo-based ratings). At the same time, the other teacher expected the opposite pattern; on the whole, she thought that the lesson in nature might leave students too keyed up to concentrate. If the nature advantage was due entirely to teacher expectations, it is not clear why both teachers showed the nature advantage.

The novelty of outdoor lessons cannot account for the nature advantage, either. If the nature advantage in subsequent classroom engagement were due to the novelty of the setting, we would expect it to decrease over the course of the semester as students habituated to having lessons outdoors. But the nature advantage was relatively stable over the course of the study.

Along similar lines, novelty of topic might theoretically account for differences in classroom engagement; each week in the study corresponded to a new topic, and if the nature lesson on a topic had generally preceded its classroom counterpart, students might have found the nature lesson more stimulating and been more engaged afterwards because of the change in topic and not because of the setting. But the order of indoor and outdoor lessons was counterbalanced such that the lesson in nature came before its classroom counterpart four times and after it six times for each teacher. Indeed, if a change in topic boosts subsequent classroom engagement, we would have expected that to result in a classroom advantage—the opposite of what we found.

In the absence of other viable explanations for the systematic pattern of superior classroom engagement after lessons in nature, it would appear that lessons in nature boost subsequent classroom engagement.

### 4.2 Accounting for the Advantage of Lessons in Nature: Active Ingredients

If lessons in nature boost subsequent classroom engagement, this raises another question: what *about* those lessons might account for this effect? That is, what is (or are) the active ingredient(s) in a lesson in nature? Previous research suggests a number of possibilities; each of these factors might contribute.

First, the *relatively natural setting* of the outdoor lessons may contribute to subsequent classroom engagement. Exposure to nature has immediate, beneficial aftereffects on both attention and stress, and is likely to enhance motivation as well. Further, contact with nature has also been shown to improve self-discipline and impulse control (e.g., Faber Taylor et al., 2002; van den Berg & van den Berg, 2011)—thus a lesson in nature might conceivably yield a quieter, less disruptive classroom afterwards. Note that the large effect sizes here were obtained even though both classrooms had window views; clearly, just providing visual access to the outdoors is not enough (see Faber Taylor et al., 2001, for findings showing better attention after being outdoors than after time indoors with a view).

Second, the sheer *break from classroom activity* involved in the walks to and from the classroom, and the *change in scenery* involved in the lesson in nature probably contribute to students' subsequent rejuvenation. Again, although this study involved formal instruction, not recess, Pellegrini and Davis (1993) and Pellegrini et al. (1995) found that elementary school children are progressively inattentive as a function of the amount of time since their last break. Another experimental study (Jarrett et al., 1998) found that fourth-graders were more on-task and less fidgety in the classroom on days when they had had recess, with hyperactive children among those who benefited the most. Thus, providing a lesson in nature may provide many of the same benefits normally accrued through recess.

Third, *physical activity* might also play a part: 10-min physical activity breaks during the school day have been shown to boost classroom engagement (Mahar, 2011), and the lesson in nature here included two 5 min (or less) walks between the classroom and the outdoor teaching setting, raising the possibility that the boost in classroom engagement here was due entirely to those walks. But most studies in the physical activity-classroom engagement literature have examined either brief bouts of intense physical activity (e.g., Mahar, 2011), or frequent, longer bouts of moderate physical activity—for example, one study examined the effects of adding roughly 190 min per week of moderate to vigorous physical activity—running, jump rope, hopping on one foot—over the course of 10 months (e.g., Kvalø et al., 2017). The dose of physical activity here was brief, light in intensity, and infrequent (two, 5 min walks per week) possibly too small a dose to improve classroom engagement.

Fourth and finally, another contributing factor may have been *impacts on teachers*. Teachers, just as much as students, might benefit from all these aspects of lessons in nature—perhaps teachers are able to teach in a more engaging way when their capacity to pay attention and interest are refreshed and their stress levels are lowered.

If so, simply giving teachers a break, a walk, and a dose of nature may have contributed to the boosts in classroom engagement seen here.

### 4.3 Generalizability

The lessons in nature here involved a particular ‘dose’ (duration, intensity, and frequency) of nature, administered in a particular way, to a particular population of students, by a particular set of teachers. Specifically, the lessons in nature in this study involved a 5-min walk from the classroom out to a grassy outdoor area with some nearby trees (Fig. 2) for a 30-min instructional period, followed by a walk back to the classroom, followed by a 5-min break—the classroom lesson involved no walking, and a 40-min instructional period followed by a 5-min break. Here, we consider reasons why the nature advantage might or might not generalize to other conditions, students, and teachers.

In combination with the study design, the findings here suggest the nature advantage could apply in a variety of conditions. The nature advantage persisted across 10 different topics and weeks in the school year; across different times of day; across two different teachers, including one who was predisposed to expect the opposite; and across two different groups of students, each with their own dynamics.

The levels of vegetation here (Fig. 2) do not seem entirely out of keeping with other schools; schools with grassy areas within walking distance might reasonably expect similar effects to those here. In schools with considerably greener surroundings, lessons in nature might have even larger impacts on classroom engagement; in one of the few studies including a wide variety of levels of nearby nature, the more natural a students’ dormitory view, the better their cognitive performance (Tennessen & Cimprich, 1995). But many urban schools might have more barren schoolyards and surroundings—in those schools, we might expect outdoor lessons to have smaller impacts. Note, however, that we might still expect an advantage—some evidence suggests children’s attention is better after time outdoors than indoors, even when the outdoor setting lacks vegetations (Kuo & Faber Taylor, 2004).

The students in this study were predominantly low-income, students of color; might lessons in nature boost subsequent classroom engagement in more well-off, predominantly White populations? Previous evidence in more privileged populations suggests they could: for example, greener school surroundings are tied to higher standardized test scores in predominantly White, relatively well-off areas, even after accounting for income (e.g., Matsuoka, 2010; Wu et al., 2014).

The teachers in the study were both highly experienced, had in-service training in outdoor and environmental education, and were open-minded as to what the study might reveal. Their relevant in-service training is likely to have given them more confidence in offering lessons in nature—and, as highly experienced instructors, they may have been more adept at recognizing the need for adjustments and making them. It seems plausible that teachers without such training, and teachers adamantly opposed to lessons in nature, might show smaller effects or even none at all.

### 4.4 Contributions to the Science of Nature-Based Learning

The findings here fill a gap in the previous literature on the impacts of nature on human functioning. Previous experimental work has shown immediate aftereffects of contact with nature on a variety of factors in classroom engagement—the ability to pay attention, intrinsic interest in learning, impulse control, and stress. Simultaneously, large-scale correlational work has tied greener near-school landscapes with better school-level performance on standardized academic achievement tests—even after controlling for socioeconomic and other factors. These two lines of investigation examine different kinds of functioning, scales of analysis, and units of time. The work here bridges the two lines of investigation, pointing to a potential pathway between the two.

Boosts in classroom engagement might be a steppingstone by which nature's immediate effects on an individual student might ultimately translate into long-term improvements in academic outcomes at the school level. Boosting attention, intrinsic motivation, and discipline in a student while simultaneously reducing their stress seems likely to have synergistic effects on their engagement in the classroom. Similarly, boosting engagement in multiple students in the same class is likely to result in synergies; when many of the students in a class are quieter, more focused and less disruptive, overall classroom engagement is likely to be much fuller and more sustained. These two synergies—between different psychological processes within individual students, and between students within a class—may explain the size of the nature advantage seen here at the classroom level. Furthermore, because classroom engagement is an important contributor to long-term academic achievement (Godwin et al., 2016; Skinner & Belmont, 1993), small but consistent improvements in classroom engagement over the course of a school year might have a surprisingly large cumulative effect on learning. Theoretically, this may help explain how relatively small differences in near-school green cover have been tied to significant differences in end-of-year standardized test performance (e.g., Matsuoka, 2010; Kweon et al., 2017; Sivarajah et al., 2018; Hodson & Sander, 2021; Kuo et al., 2018, 2020).

### 4.5 Implications for Educational Practice

The findings here provide some support and guidance for including more lessons in nature in formal education. For teachers who have been intrigued by the potential of lessons in nature but have been concerned about negative aftereffects on classroom engagement, the findings here directly address that concern. For environmental educators who have been shunted aside in favor of spending instructional time on drill and practice for standardized achievement tests, the findings here may offer a valuable argument for outdoor environmental lessons. The findings here also offer some encouragement for teachers interested in trying to adopt experiential approaches to education, which are particularly well-suited for lessons in nature.

Such approaches allow students to actively use the outdoors to apply theoretical knowledge 'in the field' and undertake problem-solving and decision-making in real world scenarios. These processes may be more effective at instilling and scaffolding long-term knowledge acquisition than other instructional strategies (Ballantyne & Packer, 2002). Curriculum that could benefit from learning styles beyond auditory and visual are also particularly well-suited for lessons in nature because the diversity of topography and vegetation in natural landscapes also provide unique kinesthetic learning opportunities (Auer, 2008; Fjørtoft & Sageie, 2000).

In students facing challenges associated with poverty, minority status, or both, academic achievement is a pressing concern. In a comparison of rich and poor school districts, sixth graders in the richest school districts were four grade levels ahead of children in the poorest districts (Reardon et al., 2016). In this population, then, the finding of an inexpensive educational practice with a consistent, large, positive effect on classroom engagement raises exciting possibilities.

While we do not know to what situations and populations the effects here will generalize, the consistency and size of the effects suggest that lessons in nature are worth trying in a broad range of settings. It is worth noting that the nature advantage, while consistent, did not occur in every pair of lessons; notably, for one teacher the first classroom lesson outperformed its outdoor counterpart. Thus, we encourage teachers to try at least two or three lessons in nature before assessing their value.

More broadly, the findings here underscore the growing view that classroom engagement is at least as limited and valuable a resource as instructional time. With the advent of No Child Left Behind legislation, the vast majority of U.S. school administrators reduced or completely cut recess time and other breaks during the school day, with the primary motivation of providing more instructional time for standardized test preparation (Robert Wood Johnson Foundation, 2010). Instructional time has been viewed by many administrators as the key, limited resource for improving academic achievement; consequently, the de facto approach to increasing student learning has been to free up instructional time by cutting school activities seen to be unhelpful to standardized test preparation—recess, physical education, art, music, theater, etc. Yet increasing the number of hours in the classroom does not translate to increasing the number of hours of student are attentively learning (Gettinger & Seibert, 2002). Estimates suggest students spend 10–50% of their time at school *unengaged and off-task* (Hollowood et al., 1994). Like pouring tea into an already full teapot, giving teachers more time to deliver standardized test content is of little value if the vessels are unable to receive. Thus, classroom engagement may in fact be the key, limited resource in academic achievement.

## 5 Conclusion

This study is the first to our knowledge to directly examine the effects of lessons in nature on subsequent classroom engagement. We found higher levels of classroom engagement after lessons in nature than after carefully matched classroom-based counterparts; these differences could not be explained by differences in teacher, instructional approach, class (students, classroom, and class size), time of year, or time of day, nor the order of the indoor and outdoor lessons on a given topic. It would seem that lessons in nature boost subsequent classroom engagement, and boost it a great deal; after a lesson in nature, teachers were able to teach for almost twice as long without having to interrupt instruction to redirect students' attention. This nature advantage persisted across 10 different weeks and lesson topics, and held not only for a teacher with positive expectations for nature-based lessons but also for a teacher who anticipated negative effects of such lessons. The findings here suggest that lessons in nature allow students to simultaneously learn classroom curriculum while rejuvenating their capacity for learning, "refueling them in flight." Because providing children with more contact with nature in the course of the school day is likely to yield a whole host of additional dividends as well, including improved physical and mental health (see Chawla, 2015 for review), the findings here argue for including more lessons in nature in formal education.

## Recommended Further Reading

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2. Children and Nature Network resources for schools: https://www.childrenandnature.org/schools/
3. Miller, N. C., Kumar, S., Pearce, K. L. & Baldock, K. L. (2021). The outcomes of nature-based learning for primary school aged children: a systematic review of quantitative research. *Environmental Education Research*, 1–26. https://doi.org/10.1080/13504622.2021.1921117

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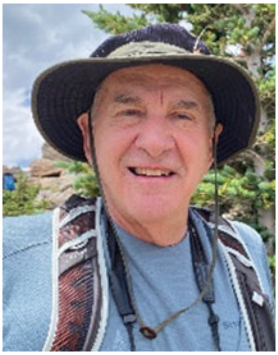

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