The impact of outdoor science instruction on middle school students' understanding of the science process

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Abstract The Kids in the Woods program in Gainesville, Florida delivers science instruction to middle school students through a series of hands-on activities outdoors on the school campus and in a nearby nature park. This article reports on the results of a 10-question pre-post assessment of students' knowledge of the scientific process. Participants included 201 6th grade students at a public middle school participating in the Kids in the Woods program. Students improved significantly on four of the ten questions after participation in the program, indicating that students learned important terminology related to the scientific method and how to interpret a graph. The positive results suggest that using the outdoors as a platform for science education can be a valuable tool for improving the learning experience for students.

Keywords Education, outdoor learning, school, science

Introduction

The use of the outdoor environment for teaching and learning is often neglected in traditional K-12 education in the United States today. However, a growing body of evidence demonstrates the wide range of benefits learning in a natural environment can provide students (Becker et al. 2017, Kuo, et al. 2019, Rickinson 2004). One of the most well-researched effects of incorporating outdoor learning into schools is an increase in students' academic performance. For example, Lieberman and Hoody (1998) found that that classes with environmental education programs, which generally included an outdoor component, were associated with increased standardized test performance, increased engagement, and reduced classroom management problems compared to classrooms without environmental education programs. There may also be an increase in science scores after participation in an outdoor education program (American Institutes for Research 2005). A number of studies examining various programs and curricula such as environment-based, place-based, and other similar pedagogy that involve outdoor or project-based learning have found gains in academic achievement (Falco 2004), improved

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standardized test scores (Danforth et al. 2008), increased performance in science (Emekauwa 2004), and increased student motivation (NEETF 2000).

Simply exposing students to natural environments can affect academic performance. A study of Massachusetts elementary schools reported a positive association between student performance and greenness of school surroundings (Wu et al. 2014). Matsuoka (2010) found that schools with views of more natural features were associated with higher standardized test scores and graduation rates, and "green school grounds," which refer to school grounds with natural elements, positively influenced students' learning, social interactions, and health (Dyment 2005). The evidence for the positive effects of green space increasingly suggests that exposing students to the outdoors during school hours is beneficial for students.

Incorporating the outdoors into education is particularly appropriate for science learning. Many science concepts, particularly related to the natural sciences, can be taught most effectively outdoors, where students can make real-life connections with the concepts they are learning. In addition, teachers often observe that students are more engaged during science lessons taught outdoors (Rios & Brewer 2014). Outdoor science education is well-suited to the type of inquiry-based science instruction outlined by the 1996 National Science Education Standards. According to the 1996 standards, inquiry includes "asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments" (National Research Council 1996). The more recent Next Generation Science Standards (NGSS) also emphasizes the use of inquiry-based instruction, in which students develop critical thinking skills through asking questions, testing explanations, and communicating ideas (NGSS Lead States 2013). There are many types of outdoor experiments and activities that effectively incorporate inquiry-based instruction and hands-on activities.

Outdoor Science Learning in the Kids in the Woods Program. The Kids in the Woods program's primary (www.campkidsinthewoods.org/school-year-program) goal is to provide 6th grade students with outdoor science learning experiences. The program includes a series of three week-long modules on bird-feeding behavior, creek erosion and deposition, and urban tree identification and benefits. Each of the program activities aims to increase students' understanding of the scientific process while exposing them to their local environment. Program activities are hands-on and interactive, and students gain experience conducting experiments and analyzing data. The program also exposes students to professionals in natural resource fields, since each module is led by scientists from various natural resource sectors.

The present study was part of an evaluation to examine the impact of the program on students' knowledge and understanding of scientific concepts. Since there is considerable research on the benefits of outdoor exposure and the educational value of experiential and inquiry-based learning, we hypothesized that the Kids in the Woods program's combination of novel outdoor experiences with

Table 1. Scores on pretest and posttest Scientific Method Assessment

Question: Topic	% Correct (Pretest)	% Correct (Posttest)	% Difference
Q1: Hypothesis	72	76	+4
Q2: Constant	27	49	+22 ***
Q3: Control group	42	53	+11 *
Q4: Independent variable	49	51	+2
Q5: Dependent variable	50	61	+11 *
Q6: Experimental design	62	63	+1
Q7: Validity	75	71	-4
Q8: Graph interpretation	26	45	+19 ***
Q9: Graph interpretation	51	54	+3
Q10: Scientific method steps	37	38	+1
Total	49	56	+7 *

* $p<.05$; ** $p<.01$; *** $p<.001$

hands-on learning would lead to gains in knowledge of the science content presented during the program.

Materials and Methods

A pretest/ posttest study design was used to assess the program's impact on students' knowledge of the scientific process. A 10-question assessment was developed by program partners and middle school teachers involved with the program (Appendix A). Questions focused on aspects of the nature of science and the scientific method emphasized throughout the program. Each multiple-choice question had four possible answers. Assessments were administered during science classes by a researcher. The researcher explained that the assessment would be used for research and would not affect students' science grades. Students were assigned numbers to ensure anonymity and to match pretest and posttest scores. The pretest was administered in September 2017, prior to any Kids in the Woods program activities, and the posttest was administered in May 2018 after completion of all program activities.

Scores were totaled for each assessment based on the number of correct answers out of ten. Assessments with more than three questions left unanswered were not scored. Only participants who completed both pre and posttests were included in the analysis ($n=202$). The internal consistency, an assessment of whether the questions or items in a test reliably measure the same construct, was first examined by computing Cronbach's alpha. Results showed that the Cronbach's alpha was .538 for the pretest and .624 for the posttest, below the generally accepted threshold for internal consistency of .70. A Cronbach's alpha lower than .70 indicates that the items may not adequately measure the same underlying construct, in this case, knowledge of the scientific method and science process.

Since the assessment as a whole was not determined to be sufficiently reliable, we examined the change in scores for each question rather than the differences in mean scores on the pretest and posttest. Examining each question also better allowed us to understand the knowledge gained for different science terms and concepts. A McNemar's test was chosen since it is appropriate for the paired, nominal data from the student's pretest and posttest scores. A McNemar's test was computed for each of the 10 questions on the assessment to determine if the change from pretest to posttest was statistically significant.

Results

A McNemar's test for each question found a statistically significant increase in scores from pretest to posttest for four of the ten questions (Table 1), showing that knowledge increased from pretest to posttest. The four questions with statistically significant improvement asked students about different topics of the scientific method and scientific process. The questions asked students about common science terminology used in experimentation. More specifically, scores improved on questions that asked students to identify a constant, control group, and dependent variable from a scenario about a hypothetical experiment. Scores also improved on one of two questions asking students to interpret a graph.

Overall, scores improved on nine of the ten questions of the assessment, but the increase was not statistically significant for five of the questions. These questions asked students to identify the hypothesis and independent variable in a scenario, identify the next step of the scientific method in a scenario, and interpret a graph. Scores decreased on one question from pretest to posttest, although the difference was not statistically significant. In this question, students were asked what a to do in a scenario in which a mistake is made while collecting data.

Discussion

Results show that students' knowledge of the scientific method and the scientific process improved significantly from the beginning of the school year, before Kids in the Woods program activities, to the end of the school year, after completion of all Kids in the Woods program activities. Students were better able to identify a constant, control group, and dependent variable in an experiment and interpret a graph. The activities in the Kids in the Woods program aim to reinforce these ideas. In each module of the Kids in the Woods program, particularly the module on bird feeding behavior, program leaders stress scientific terms. During the analysis portion of each module, students practice interpreting different types of graphs. The results of the study suggest that Kids in the Woods program activities, including hands-on practice conducting experiments, helped students understand important terms associated with the scientific method.

There were, however, some limitations due to study design and other factors encountered during administration of the tests. The study did not include a control group, and thus it is difficult to rule out confounding factors. Researchers also encountered some issues during test administration. Because the assessment was voluntary and did not factor into students' grades, it was observed that many students chose not to take the assessment or did not read and answer the questions carefully. This may have affected scores since some students did not give their full attention to the assessment. In addition, many classes were administered posttests during the week of their state exams, which is a stressful time for students and often leads to mental fatigue. Some other classes were administered posttests during the final week of school before summer break, when students tend to be less motivated to complete assignments. We would expect that under different circumstances, students would have performed better on the posttest. Despite the issues encountered, performance on the assessment increased significantly.

Another potential limitation lies with the instrument used in the study. The assessment's low internal consistency shown by the Cronbach's alpha revealed that the questions in the assessment may not have captured the broad range of science process knowledge intended. Due to the constraints of conducting research in a school environment, it was not feasible to include a pilot test for the instrument. We chose a 10-question assessment to limit the amount of valuable class time taken by the research project. An assessment with more questions may have had better internal consistency. Additionally, scores on most questions were low on both the pretest and posttest, indicating some questions were difficult or perhaps not well-understood by students. A more thorough testing of the instrument would have strengthened the study.

The study was useful in determining which areas of the Kids in the Woods program activities could be improved. For example, the results showed that students' understanding of the independent variable and the steps of the scientific method improved only marginally, demonstrating that activities may need to be tailored to better explain these topics. Evaluations such as the present study can help identify content in the program that can be revised and improved. A continual updating of both the program activities and the evaluation can lead to a more valuable learning experience for students.

Overall, the study suggests that experiential, hands-on learning in an outdoor setting can be a valuable tool to improve school-based science education. Outdoor learning activities such as the ones used in the Kids in the Woods program could be utilized by many schools. Green space within schoolgrounds and near schools offers an opportunity for additional learning outside of traditional classroom instruction. Many different topics in science could be applied in outdoor experiments. Through conducting real-world science projects in a novel environment, students gain memorable experiences and a more in-depth connection with the scientific process.

Incorporating the outdoors into regular classes has the potential to improve the educational experience for students and help students accrue the many physical and health benefits of exposure to nature and the outdoors. As teachers and schools incorporate outdoor learning into the curriculum, it is important to continue to evaluate the effectiveness of these methods. More rigorous and in-depth studies are needed to better understand the effects of school-based outdoor experiences.

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Appendix 1.
Scientific Method Assessment

Betty has a problem with squirrels eating the bird seed from her bird feeders. She wants to know if adding hot pepper to bird seed will help prevent squirrels from eating the bird seed on the bird feeders. She decided to conduct an experiment. She set up four identical bird feeders around school campus. She put bird seed mixed with hot pepper in feeders 1 and 2 and normal bird seed in feeders 3 and 4. She counted the number of squirrels that ate bird seed on the bird feeders for 10 minutes each day for 10 days.

1. The hypothesis is: If hot pepper is added to bird seed, then….
   a. More birds will not eat the bird seed because the squirrels do not like to eat hot pepper.
   b. More squirrels will eat the bird seed with hot pepper because hot pepper attracts birds.
   c. Less squirrels will eat the bird seed with hot pepper than the regular bird seed because the squirrels do not like to eat hot pepper.
   d. Less birds will eat the bird seed with hot pepper because birds do not like to eat hot pepper.

2. Which of these factors is a constant in the experiment?
   a. Hot pepper added to the bird seed
   b. Type of bird feeder
   c. Number of squirrels
   d. The weather

3. Which of the four feeders is the control group?
   a. Feeder 1 only
   b. Feeders 1 and 2
   c. Feeders 3 and 4
   d. Feeder 4 only

4. What is the independent variable in the experiment?
   a. The number of squirrels counted at the feeders
   b. The time of day
   c. The hot pepper added to the bird seed
   d. The students observing the birds

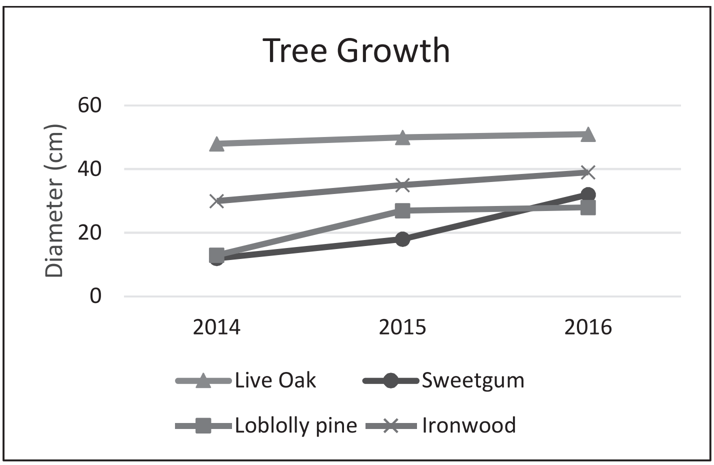
5. What is the dependent variable (outcome variable) in the experiment?
   a. The number of birds counted at the bird feeders
   b. The students observing the birds
   c. The number of squirrels counted at the bird feeders
   d. The amount of hot pepper on the bird feeders

Billy walks home from school every day and passes by a creek. He notices that the creek looks different than last year. Some parts of the creek seem wider and other places narrower than before.

6. Billy hypothesizes that over time, the shape of creek changes due to natural processes such as erosion and deposition. How should he test his hypothesis?
   a. Measure the characteristics of the creek at the start and end of the year.
   b. Analyze the data he has collected on the creek by averaging the results.
   c. Guess the size of the creek bed by estimating the width of the creek.
   d. Make conclusions based on his hypothesis.

7. Billy tested his hypothesis and found that the creek is changing over time. However, he thinks he might have made a mistake while measuring the creek and is unsure his results are valid. What should he do to check his results?
   a. Change the lab report.
   b. Perform a new study.
   c. Repeat the same study.
   d. Analyze his data again.

Stephanie observed that some species of trees in her backyard grow faster than others. She identified and measured several trees in her backyard three years in a row, from 2014 to 2016. The graph below shows the growth of four different species of trees in Stephanie's backyard from 2014 to 2016.



8. Based on the graph, which species of trees grew the most (in diameter) from 2014 to 2015?
   a. Live oak
   b. Sweetgum
   c. Loblolly pine
   d. Ironwood

9. What can Stephanie infer based on the graph?
   a. Live oak grew more than any other tree from 2014 to 2016.
   b. Ironwood grew more than loblolly pine from 2014 to 2015
   c. Loblolly pine grew more than Sweetgum from 2015 to 2016.
   d. Sweetgum grew more than any other tree from 2015 to 2016.

10. Stephanie thinks that the trees in the park are bigger than the trees in her backyard. She collects data on 15 trees in each site. What should her next step be?
   a. Research how trees affect the ecosystem.
   b. Make conclusions about which site has bigger trees.
   c. Measure and record the diameter of trees at both sites.
   d. Analyze the data on trees in the park and in her backyard.