"Sometimes you're not Wrong, you're just not Right": Advancing Students' Epistemic Thinking about Science through in-School Citizen Science Programs (Short Paper)

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"לפעמים אתה לא טועה, אתה פשוט לא צודק": קידום החשיבה האפיסטמית של תלמידים על מדע באמצעות שילוב מדע אזרחי בבתי ספר (מאמר קצר)

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Abstract

Helping K-12 students reach a constructive understanding of what science is has been a long-standing goal and an ongoing challenge of science education. One promising path to attain this objective lies with citizen science initiatives, which involve non-scientists in the practice of science. Nonetheless, little is known about strategies to meaningfully integrate citizen-science-based learning with in-school science education. This paper presents a preliminary study about an in-school program in which 69 4th-graders and 59 9th-grades took an active role in a citizen science research. Our goal was to characterize the development of students' epistemic thinking about science and delineate factors that contributed to its advancement. Developing a rubric to score students' written answers to an open-ended question; "what does it mean to study something scientifically?", our analysis indicates that both 4th and 9th-graders have advanced their epistemic thinking about science. In addition, we provide sample quotes from semi-structured interviews,

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demonstrating the nature of the observed changes. We conclude that citizen-science-based programs in schools can contribute to the advancement of students' epistemic thinking about science, even in low grades. We briefly discuss what elements of the program may have inspired such gains.

Keywords: Citizen science, Epistemic thinking about science, Formal science education.

Introduction

Helping K-12 students reach a constructive understanding of what science is has been a long-standing goal and an ongoing challenge of science education (Lederman, 1992; NRC, 2012). There is a continuous debate regarding what students should learn about science, and how to teach such concepts (Osborne et al., 2003; NRC, 2007).

In citizen science, non-scientists actively participate in the production of scientific knowledge by contributing to scientist-led research, collaborating with scientists, or leading their own investigation (Shirk et al., 2012). Positive effects on citizen scientists' epistemic thinking about science was shown in several studies (e.g., Price & Lee, 2013), few of which performed with school students (e.g., Ruiz-Mallén et al., 2016). Such findings make the integration of citizen-science-based learning within schools a promising approach for strengthening science education, yet, the existing body of research falls short of providing design principles and guidelines on how to accomplish such outcomes.

This paper presents a preliminary study about an in-school program in which students took an active role in a citizen science research. Our goal was to characterize the development of students' epistemic thinking about science and delineate factors that contributed to its advancement.

Methodology

Participants and Intervention

Students from two schools in Israel (69 4th-graders and 59 9th-graders) participated in an in-school citizen science program whose curriculum was jointly developed by the authors of this paper and the students' teachers. The students took part in an academic ecological research in collaboration with the ecologist (a co-author of this paper). Based on the collection of footprint data, this research sought to assess population sizes of small mammals and their relation to different land uses.

The curriculum included activities designed to match students' age and the teachers' educational goals. In the 4th-grade, the program emphasized environmental awareness and student empowerment. Following introductory lessons, a meeting with the ecologist, and learning of the data-collection methodology, the students collected a large portion of the research data. By learning to identify relevant mammalian species via footprint analysis, they were also minorly involved in processing their own data. They later explored the species map compiled by the ecologist.

The 9th-graders conducted a small investigation within the larger ecological research, comparing species richness across three locations--a residential area, an open area, and a grazed grove. This included articulation of research questions, hypothesizing, collecting and analyzing their own footprint data with the assistance of the ecologist, and collaborative writing of a whole-class scientific report, with the teacher's support.

Data Collection

Students completed a pre-post questionnaire which included an open-ended question intended to assess students' epistemic thinking about science: "What does it mean to study something scientifically?" (Brossard et al., 2005). In addition, pre and post semi-structured interviews were conducted with twenty-five 4th-graders and nine 9th-graders.

Data Analysis

For this paper, we concentrated on analysis of the specific question noted above, and solely on what the responses reveal about students' epistemic thinking about science. The existing rubric was found unsuitable for our data, as students' answers were highly diverse and related not just to epistemic aspects. Using theme definitions taken from a study of "ideas-about-science" noteworthy of teaching in schools (Osborne et al., 2003), we identified five different epistemic themes in students' answers. The rest of our analysis focused on the "Hypothesis and Prediction" theme, which was found abundant in students' answers and seemed to have undergone changes between pre and post data (22% and 26% of 4th-grade student answers related to this theme in pre and post questionnaires, respectively. In the 9th-grade, the respective number of answers was 52% and 46%). To examine this, we developed a scoring rubric based on the theme's definition (Table-1).

Table 1. Scoring rubric for the "Hypothesis and Prediction" theme, with representative sample quotes taken from students' answers

Score	Definition	Sample Quote
0	Science as "fact collecting", gathering of information	*"Investigating its properties, its characteristics"*
1	Science as discovering/finding answers, or empirical data collection	*"It means observing something, measuring its size and discovering new things about it"*
2	Science as deriving explanations from empirical evidence	*"Doing an experiment and drawing conclusions from the results"*
3	Science as a testing of theory	*"Doing an experiment to draw a conclusion that either supports or disproves your claim"*

We scored only answers related to this theme. The results were tested for the null hypothesis that pre and post distributions are equal, using Fisher's exact test. This test was chosen despite the apparent violation of independence, as a large proportion of the pre-post values were not paired (typically, students' answers related to the theme in only one of the pre-post questionnaires).

To further substantiate the questionnaire analysis, we provide utterances from interviews with two students illustrating typical pre and post answers which we analyzed with the same rubric.

Results

Questionnaires

The prevalence of each score in students' answers is shown in Figure-1. Fisher's exact test suggests that for both 4th-grade and 9th-grade values, the pre-post distributions are not equal. P-values for the 4th and 9th grades were 0.0196 and 0.0094, respectively.

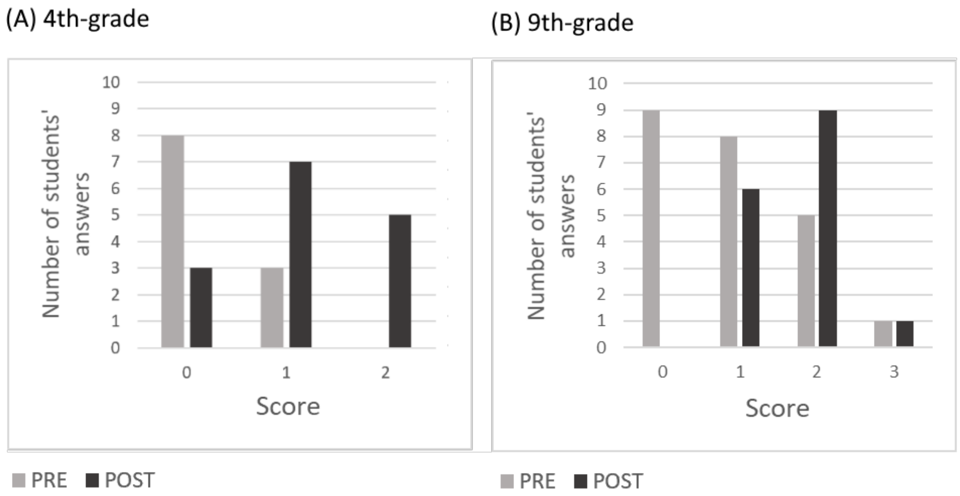

Figure 1. Prevalence of scores for the "Hypothesis and Prediction" theme, in students' responses to the epistemic question in the questionnaire.

Interviews

Analysis of the interviews provides further understanding of how students' thinking about this epistemic theme has changed. We show samples from two cases, a 4th-grader in Table-2, and a 9th-grader in Table-3.

Table 2. Quotes of a 4th-grade interviewee, scored using the rubric

Interview	Quote	Score
PRE	"[Researching] is finding out new things about something... if we are researching the honey badger, then we will know new things about it that we didn't know before."	0-1
POST	"If I look at a research, I'm not saying it will be true and I'm not saying everyone should believe it's right… say, [the ecologist], I say he's right but I'm not saying everyone should say he's right… I think he is right because he has done a very thorough research and he's going to keep doing it in the following years… and I know what we did seems correct, and we checked it."	2

Table 3 Quotes of a 9th-grade interviewee, scored using the rubric

Interview	Quote	Score
PRE	"Once [something scientific] is accounted for, and you see it has many explanations and lots of scientific proofs, then it is credible."	2
POST	"We understood the difference between conclusions and hypotheses… we thought we'd get the least number of animals here, a hypothesis that was refuted. We rephrased a new hypothesis, or taken down some factor and then we understood it, we said, let's try without cats in the residential area, and then we saw that there really were no wild animals here… we understood that sometimes you're not wrong, you're just not right."	3

Discussion and Conclusions

Both 4th and 9th-graders have advanced their epistemic thinking about science, as shown in their answers to the questionnaire. The samples from two interviewees demonstrate the nature of observed changes. We believe that the designed citizen-science-based curriculum had an important role in this development: The 9th-graders tested a hypothesis in a real-world setting, in a complex ecological environment for which little prior knowledge existed. Incidentally, during this process they had to make sense of evidence that contradicted their initial reasoning. They authored a scientific report and four representatives presented their work for out-of-school evaluation. The 4th-graders focused on data collection, yet there was an emphasis on explaining the "why and how" of the data collection methodology, as well as some discussion on the validity of the results. On three occasions they had a meaningful interaction with the ecologist.

We conclude that citizen-science-based programs in schools can contribute to the advancement of students' epistemic thinking about science, even in low grades. To encourage the development of such programs, it is important to further substantiate what activities and thought processes inspire such gains.

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