PROJECT REPORT

The Clean Air and Healthy Homes Program: A Model for Authentic Science Learning

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Abstract

The Clean Air and Healthy Homes Program (CAHHP) is a science education outreach program that involves students in research of their own design related to indoor and outdoor air pollution and links with respiratory health. The program, which provides equipment, lesson plans, and support to middle and high school classrooms and professional development for teachers, is an excellent model of how to engage students in relevant and authentic science research and learning. This article describes the current program, how it promotes authentic science learning in secondary science education, and the positive impact it has had on student learning and attitudes.'

Introduction

Providing students the opportunity to truly *do* science has been shown time and time again to positively influence their science learning experience, including increasing students' interest in science (Ainley et al. 2002; Hasni and Potvin 2015; Palmer 2009; Potvin and Hasni 2014; Rivera Maulucci et al. 2014; Sadeh and Zion 2011; Spronken-Smith et al. 2012; Swarat et al. 2012). Other studies have reported that students engaged in inquiry-based learning focused on the process of science actually improved performance on achievement tests (Abdi 2014; Blanchard et al. 2010; Schneider et al. 2002). With the development and adoption of the Next Generation Science Standards (NGSS) (National Research Council 2013), teachers have been further encouraged to step away from the traditional teaching of discrete facts to a broader exploration of the world around us via inquiry-based learning. Through collaborative programs, there is now more opportunity than ever to engage students in the process of meaningful, authentic science learning.

The Clean Air and Healthy Homes Program (CAHHP) is a science education outreach program designed to offer middle and high school students the opportunity to

explore a real-world issue through authentic scientific research in their homes and communities. Originally named *Air Toxics Under the Big Sky*, the program has evolved and grown significantly since its inception in 2003 (Adams et al. 2008; Marra et al. 2011; Ward et al. 2008). Its success and growth can be largely attributed to its adherence to SENCER ideals and to the early influence and support from the SENCER community, as originally reported in this journal in 2007 by Jones et al.

Through CAHHP, students learn about three air pollutants (particulate matter, radon, and carbon monoxide) that not only cause adverse health effects, but are also commonly found in indoor environments such as homes and schools. Exposure to airborne particulate matter can result in respiratory and cardiovascular diseases (Environmental Protections Agency 2016) while radon is the second leading cause of lung cancer behind cigarette smoke (National Cancer Institute n.d.). Carbon monoxide is responsible for an average of 15,000 poisonings and 500 deaths in the United States each year (Centers for Disease Control and Prevention 2014). By participating in CAHHP, students begin to understand the link between their health and their own exposures through authentic research and data collection.

CAHHP takes place over the course of an entire school year and engages secondary school students living in rural areas of Montana, Idaho, and Alaska in scientific research focused on indoor air quality issues. This indoor component is an important focus, as the average American spends over ninety percent of his/her time indoors (Klepeis et al. 2001). Since the program's inception in 2003, we have worked with thousands of students in more than 40 schools. In the current school year alone (2015/2016), we have more than 800 students doing research projects in the classrooms of 30 teachers. The program is being implemented in a variety of subject areas including chemistry, environmental science, physical science, IB Environmental Systems and Societies, and anatomy and physiology.

Overview of the Program

CAHHP has three primary goals: (1) to develop and provide inquiry-based, learner-centered instructional materials and opportunities; (2) to implement these materials in rural underserved areas; and (3) to provide professional development opportunities for teachers interested in environmental health sciences. The following overview summarizes the program's activities throughout the course of a year.

Professional Development

The first step for a teacher who wants to implement the program in his/her classroom is to attend a two-day summer workshop. During this time, teachers learn about the three pollutants (particulate matter, carbon monoxide, and radon), receive an overview of the available lesson plans, perform a number of the inquiry labs included in the program, discuss strategies for and the value of supporting student research, and receive training on the air sampling equipment that is provided to the classroom. Teachers also have the opportunity to interact with colleagues who teach in the same content areas to discuss classroom implementation strategies. Additionally, expert "veteran" teachers share insights on how to successfully support student research and integrate the program into the classroom.

Classroom Visits

The summer workshop is followed by a visit to the teachers' classrooms, either in person or remotely via Skype, by a member of the CAHHP team. A presentation is given introducing students to concepts regarding air quality and respiratory health, including an overview of the program.

Lesson Plans and Supplemental Materials

Teachers have a number of lesson plans available to them for student exploration of the air pollutants throughout the school year. All lessons were developed in partnership with expert science teachers, as well as with research scientists in the field of environmental health sciences. Each lesson is tied to state and national standards and promotes the three-dimensional model of learning supported by the NGSS, as well as at least one guided inquiry lab illuminating a key concept related to one of the pollutants, its formation, and/or related health effects. A summary of all available lesson plans available through CAHHP can be found in Table 1. Table 2 displays the various learning units in which the lesson plans fit within a variety of classrooms.

Designing and Executing a Research Project

Once familiar with the pollutants, students identify a testable question and design a research project. To identify their questions, they are encouraged to consider the indoor environments in which they spend the majority of their time (home, school, and work) and what their potential pollutant exposures are within these environments. They are also encouraged to consider their communities and the specific, possibly seasonal, air quality issues that may impact them. Students can use one of three pieces of equipment provided by the program (see Figure 1) to perform their research. After identifying their question and developing a hypothesis, students then collect and analyze their data. Examples of student research projects from recent years are found in Table 3.

Presenting Findings

At the conclusion of each school year, students and teachers are invited to visit the university campus to attend the annual CAHHP Environmental Health Science Symposium, during which they present and defend their work either via a PowerPoint presentation before a panel of judges and between 100-200 of their peers, or through a scientific poster. The top three projects in each category receive awards. For many students, this is the highlight of their CAHHP experience. Evaluation data show that students benefit from participation in the symposium in a variety of ways (Vanek et al. 2011). For example, students have reported increased self-confidence in their ability to respond to challenging questions and potential criticism, as well as understanding the importance of being well prepared and practiced.

For students who cannot attend the symposium, there are many other options for formal presentation of student findings, including regional and state science fairs, community health fairs, and individual school events such as presenting research at parent night. Participation in one of these events is key, as findings from a study focused on inquiry-based science curricular initiatives developed between 1998 and 2007 found that only about 10 percent of projects emphasized presenting and communicating findings (Asay and Orgill 2010).

Beyond Student Learning Opportunities

In addition to providing meaningful learning opportunities, CAHHP encourages multiple community partnerships. Groups such as the American Lung Association, state, city, and county health departments, and Area Health Education Centers (AHEC) have created mutually beneficial relationships with CAHHP that expose students to possible future careers in the field of science and provide them an opportunity to do work directly for the community. For example, in a collaborative effort between the Montana Department of Environmental Quality and a student from a high school Geographic Information Systems (GIS) course, an interactive map of radon levels from more than 500 homes in the state was generated. This highlights not just the aspect of collaboration, but also the potential for citizen science opportunities. Data collected by students can be compiled, mapped, and used to inform the public and warious agencies on trends in air pollution. Students also have the opportunity to directly improve the air quality in their schools and homes. One group of students found high levels of radon in their public school building and collaborated with a local radon mitigator to engineer and install a successful remediation system. Past monitoring of particulate matter levels in schools has resulted in heating/cooling system maintenance and even the replacement of the ventilation system in a wood shop at one school after consistently elevated particle levels were measured.

What Students Are Taking Away from the Program

Findings from an external evaluation showed that students who participate in CAHHP demonstrate a deeper understanding of the process of science, and express an increased interest in science as a content area (Ward et al. 2016). Students also consistently self-report an increased confidence in their ability to do science. For example, one student wrote that "the program taught me that I can work hard and have the ability to conduct a thorough experiment and be confident in my skills," while another reported, "The program taught me that I have the ability to accomplish anything I set my mind to and I became more interested in science."

Other comments from students on their own experience and academic growth include:

- "It was cool doing an experiment to actually benefit my school."
- "[The program] made me aware of how science can be relevant to my everyday life."
- "I learned how to properly test a question."

Conclusion

The value of authentic science learning opportunities for secondary science students cannot be emphasized enough. As our results indicate, involving students in the actual process of science, from the ground up, creates learning opportunities that improve science skills and motivation. Both of these are critical for keeping students engaged in the scientific field, as there is a delicate interplay between students having strong enough skills to feel confident pursuing science and their desire to do so. Over the last decade, *The Clean Air and Healthy Homes Program* has emerged as a successful platform for increasing students' interest in science—and interest in science as a career—while keeping with current trends in science education. The development and implementation of the Next Generation Science Standards (2013) are confirmation of the broader agreement that science learning needs to be multifaceted and must truly involve students in scientific ways of thinking and doing, not just in the memorization of scientific facts.

Additionally, when students do research within their own communities, they begin to realize that they have the

TABLE 1. Overview of available lesson plans

Particulate Matter Lesson 1: "What is Particulate Matter?"	Students explore different sources of $PM_{2.5}$ and PM_{10} using the Dylos DC1700, then observe particle formation in a micro-environment (i.e., petri dish). Students also begin to consider their own exposures to particulate matter.
Particulate Matter Lesson 2: "Health Risks of Particulate Matter Exposure"	Students assume the roles of different individuals with different health profiles in five age groups: infants, children, young adults, middle-aged adults, and the elderly. They then visit different environment stations (i.e., large city, rural agricultural area, etc.) that have differing sources of pollution and weather patterns. Based on these, they identify their potential health concerns.
Carbon Monoxide Lesson 1: "What are Complete and Incomplete Combustion?"	Students explore the reactants and products of combustion in the "Life of a Candle" lab. By subjecting a burning candle to differing conditions, they are able to deduce both visible products (soot) and invisible products (carbon monoxide) during incomplete combustion and determine the chemical equation of combustion.
Carbon Monoxide Lesson 2: "What are the Health Effects of Exposure to Carbon Monoxide?"	Students explore the physiological mechanisms underlying carbon monoxide toxicity by watching a video of a lab in which blood samples are exposed to different gases (O2, CO2, and CO) at different times. By observing blood color after exposure, students discover that CO bonds more tightly to hemoglobin and inhibits continued gas exchange.
Radon Lesson 1: "What is Radioactivity?"	This lesson introduces students to the origin of radioactive isotopes and how they interact with the environment through two labs: "Vapor Trails" in which students observe energy rays emitted by a radioactive source, and "Pennicium, Pennithium, and Pennium" in which students use pennies to simulate the decay process of different "isotopes" to determine the equation for half-life.
Radon Lesson 2: "What is Radon?"	Students learn about radon, its origin, and how it enters the environment. They examine radiation produced by different materials, how distance is related to radiation dose, and how various shields can alter the emission of radiation.
Radon Lesson 2: "What are the Potential Health Effects of Exposure to Radon Gas?"	To understand the relationship between radon exposure and respiratory health, students participate in a simulated epidemiology study to explore the correlation between radon and lung cancer.

TABLE 2. CAHHP Materials and Learning Units

	Particulate Matter	Radon	Carbon Monoxide
Physical Science and Chemistry	▪ Atoms and Compounds	▪ Nuclear Decay ▪ Isotopes ▪ Balancing Nuclear Equations	▪ Conservation of Mass
Biology	▪ Respiratory System ▪ Genetics (epigenetics)	▪ Genetics (genetic mutation and cancer)	▪ Circulatory System ▪ Respiratory System
Earth Science	▪ Meteorology		Chemistry

TABLE 3. Examples of student projects

Pollutant	Project Title
Particulate Matter	"Air quality in indoor swimming pools—An exploration of particulate levels in indoor pool facilities during low and peak use"
Particulate Matter	"Ski-entifically proven: Ski waxing in indoor environments"
Particulate Matter	"Roundabouts vs. traffic light intersections and their implication on air quality"
Carbon Monoxide	"CO output levels of different types of automobiles"
Radon	"Differences in indoor radon levels in Kootenai Valley homes with respect to soil type"

ability to collect meaningful data and to use that information to directly make a difference in their own lives and those of others in their community. They become stakeholders in their own well-being and have the potential to make tangible changes through their research. They also have the opportunity to meet and interface with professionals whose lifework is committed to improving quality of life for the average citizen through science. The more science becomes a concrete practice for students and not a set of abstract ideas, the more likely they will use and engage in science in their daily lives. In this way, programs like CAHHP provide valuable opportunities to make science learning more meaningful and effective. In the future, we will continue to engage schools in rural and underserved areas, supporting students in conducting authentic research focused on reducing exposures to air pollution while improving health within their homes and communities.

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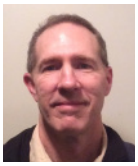

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