ILLUMINATIONS | K-12 Outreach

Second graders and their teacher have PhUn learning about thermoregulation

Patricia A. Halpin,1 Connor H. Fleury,2 and Catherine Page3

1Department of Life Sciences, University of New Hampshire at Manchester, Manchester, New Hampshire; 2STEM Teaching Fellow Program, University of New Hampshire at Manchester, Manchester, New Hampshire; and 3Grantham Village School, Grantham, New Hampshire

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INTRODUCTION

Physiology Understanding (PhUn) Week is an annual event sponsored by the American Physiological Society that brings professional scientists into K–12 classrooms to perform activities and experiments with students, so that they can learn more about how science is performed (http://www.the-aps.org/mm/Education/K-12/EducationProjects/PhUn-Week) (8, 18, 21, 25). The overall goals of this successful program are to introduce students to a “real life” scientist, to increase their understanding and enthusiasm for science (11, 23). Since its inception, the number of students reached has exceeded 97,000, and the number of PhUn Week events has surpassed 600, with events taking place in 41 states, Puerto Rico, Australia, and Canada (25). For students who have participated in this program, a significant gain in science content knowledge has been demonstrated (9, 20). The long-term goal of outreach is to increase the likelihood that these students will go into STEM fields. The short-term goal is that they gain an understanding and appreciation of science and how it is performed (2, 3, 9, 12). The successful attainment of this short-term goal is becoming threatened, as we live in a world where some people believe that vaccines cause autism, climate change is not real, evolution is not science, and these beliefs are gaining momentum (10, 15). Increasing the science literacy of our population is of utmost importance, and scientists need to play a major role in delivering accurate information to the populace (11, 15, 22).

To increase the science literacy of elementary school students, their teachers need support in incorporating more hands-on inquiry-based instruction (5). Elementary school teachers often report that they lack confidence or have inadequate content knowledge to teach science (13). Current preservice teaching programs are addressing this issue by designing programs to improve teachers’ self-efficacy (19). Teachers who are well-prepared to teach science still can face constraints that obstruct the high-quality delivery of science content (13). In all situations, the opportunity to have a scientist come into the classroom and work with the students is a benefit to students and teachers alike.

The STEM (Science, Technology, Engineering, and Mathematics) Teaching Fellows are part of a new program at our college, and these undergraduates majoring in STEM fields assist a faculty member in K–12 outreach activities. These undergraduates benefit from participating in outreach activities by increasing their own content knowledge (1). For this activity, the Fellow is a first-year undergraduate student majoring in mechanical engineering.

For this PhUn Week session, a physiologist and a STEM Teaching Fellow worked with second-grade students at a small rural school. The students were introduced to the topics of homeostasis, thermoregulation, and adaptations. They performed the insulation bag activity (16, 17) and identified adaptations that polar bears and birds use to stay warm in the winter. The students recognized the differences in the adaptations of birds (feathers), and polar bears (fat) and saw how these adaptations help these animals stay warm in winter. Their teachers appreciated the experience as they learned more about physiology and could continue the lesson after the physiologist and the STEM Fellow departed.

METHODS

Introduction to Thermoregulation, Homeostasis, and Adaptations

This is the 5th consecutive year of PhUn Week at this school and the first time performing this experiment. The initial contact with this lead teacher was made through an acquaintance with her principal, who was a former lead teacher (4th grade) at a different school (9). The two second-grade classes were combined, for a total of 32 students. The introductory part of the session lasted 15 min and began with the physiologist asking the class, “What is a physiologist?” Students’ answers ranged from, “A person who studies physics,” to “A person who studies animals.” Phizzy, the physiology bear (stuffed animal) was introduced, and the children cheered (see Fig. 3). It was explained that Phizzy was here to teach the students physiology, and that physiology is the study of how the human body works. The STEM Teaching Fellow was introduced as a college student who is studying engineering. He explained, “Engineers build things, like the chairs you are sitting on.” The term homeostasis was defined as the state when all body conditions stay within a small range, and maintaining body temperature is part of homeostasis. The physiologist asked if anyone knew what the term thermoregulation meant. The students, of course, did not know this. They were then asked if they knew what a thermometer measured, and they said “temperature.” When asked what regulation meant, none of them knew. So thermoregulation was then defined as a rule, and putting the two words together meant there was a rule that your body followed to keep your body temperature within a small range. The normal human body temperature, 98.6°F, was written on the board, and it was explained that scientists use the Celsius scale, so 37°C was written down (Fig. 1) and explained as having the same value. Two specific examples were given, to help the students understand the concept of thermoregulation. A student in the first row was asked, “What will happen if you
go outside without a coat, hat, or shoes and stand in the snow?” She replied that she would get cold. The physiologist continued to prompt the class with, “Then what?” Finally one said that she would shiver and stomp her feet. The next question, “What happens to your body temperature when you stand outside in the cold?” was correctly answered, “It goes down.” The explanation was given that shivering is the body’s response to body temperature dropping, and that muscle contraction gives off heat to bring the body’s temperature back up to normal. A flowchart was drawn on the whiteboard, which helped to complete the understanding of the concept (Fig. 1).

The second example began with the question, “What happens when you go outside in the summer and you are really hot?” The students answered right away, “You sweat.” It was explained that sweat is the way the body releases heat. This prompted the students to ask and answer many questions among themselves. “How does a dog stay cool?” one asked. Another student answered quickly, “It pants.” Still another student asked, “What about a pig?” and a student answered, “It lays in the mud.” The physiologist praised them and said that sweating and shivering are how the body thermoregulates to maintain its temperature of 98.6°F or 37°C.

The poster, “How Do I Keep Warm?” was displayed, and the specific examples of the polar bear and the bird were shown (Fig. 2). When students were asked, “How do animals stay warm?” the answers given were: “hibernate,” “fur,” and “blubber.” The word adaptation was defined as something the animals had that helped them stay warm and survive in cold weather living outside. Bird feathers, and a fat layer under the fur, were both identified as adaptations that are used to stay warm in winter. When asked, “What adaptation does a human have to stay warm outside?” one student answered, “skin,” while another answered, “a jacket.” The physiologist explained that human skin is not well-adapted to keep us warm in the winter, which is why we need jackets.

The experiment to be performed would then test and compare the adaptations of birds (feathers), polar bears (fat), and humans (skin) to determine which helped keep an animal warm in winter.

Activity Book and Insulation Bag Experiment

This part of the PhUn Week session lasted about 35 min total. The first step was their teacher separated the students into two groups: the activity book group (group 1) and the experiment group (group 2). So that the students in group 1 would not feel they were being slighted by not being in group 2 first, they were given Phreezy the polar bear (stuffed animal) (Fig. 3) and told to work on page 6 of their Fun with Physiology activity book (Fig. 4) (26). This page asks, “What are the adaptations that polar bears have to stay warm?” The classroom teacher assisted this group to keep them on task.

The students in the experiment group (group 2) began with making a prediction about which type of adaptation would keep their hand the warmest when placed in a bucket of ice water.

They wrote their prediction on the back page of their activity book and were instructed, “Shhhh, don’t tell anyone your prediction as it may influence your classmates.” The students enjoyed being secretive, and these instructions increased their enthusiasm.

The insulation bag activity was set up following the instructions (17) and video by Limson (16). Two buckets filled with ice water and three types of mitts constructed of Ziploc bags were made available. The students were told that the bubble wrap-lined mitts mimicked bird feathers. Mitts lined with fat bags mimicked the insulation of polar bears, while the plain or unlined mitts mimicked human skin. Each student placed the right hand in the human skin mitt and then placed the left hand in the bird feather mitt and immersed both in the ice water to determine which mitt kept their hand warm. They were instructed to keep their results a secret in order not to influence their classmates. Then they replaced the bird feather (bubble wrap) mitt with the polar bear (fat) mitt and immersed both hands in the ice bucket once again. They returned to their seats to write down their results in their activity books. The groups then switched, and group 1...
performed the experiment while group 2 worked in their activity books.

When all of the students had completed both the activity and the experiment, the physiologist asked, “Which mitt kept their hand the warmest?” The class was equally divided between students choosing the polar bear mitts and the other half choosing the bird feather mitts. One student stated that he thought the human skin was the warmest. It is also of note that on this cold winter day (0°C) he was wearing shorts. This provided the opportunity to explain to the class that some people have naturally warm hands, and none of the mitts would seem cold to them. The words homeostasis, thermoregulation, and adaptation were redefined to reinforce the concepts.

In the final 10 min of the class period, the physiologist talked about the heart. The students correctly defined heart function as the organ that pumps blood. On the whiteboard, the four chambers were drawn as a simple box, and the path that blood moves through the heart was shown. The students were given squeeze hearts and got excited asking, “Do we get to keep them?” Together with the physiologist, they demonstrated heart contraction as they squeezed both atria with their right hand and shouted “atria.” This was followed by squeezing both ventricles with their left hand shouting “ventricles.” This contraction rhythm repeated several times with the volume of everyone shouting “atria” and “ventricles” getting louder. Then the pace of squeezing was sped up, and it was stated that this is what happens to heart rate when a person exercises. The pace was slowed, and it was stated this is what happens to heart rate as you sleep. The term homeostasis was reintroduced to describe how the heart rate can change due to activity and then return to a normal rate.

When asked how to keep your heart healthy, the students knew that exercise is important. Eating healthy food was mentioned, and several students gave examples of healthy food choices: broccoli, oranges, water, and meat. Because meat was mentioned, it was appropriate to add that one serving of meat is the size of the squeeze heart, and one serving per meal is sufficient. It was also emphasized that one-half of your plate should contain colorful food. To summarize and conclude the session, it was stated that the heart is a muscle and needs exercise to stay strong to pump blood through the body, and that healthy eating keeps your heart and whole body healthy.

The Benefits of PhUn Week Stated by the Teacher

When performing outreach, the focus is on the students, and the benefits to the teachers are usually not investigated. To focus on this aspect of the outreach session, the teacher was sent an e-mail 1 day after the session, and the following responses were received.

A. How does the PhUn Week activity affect teacher content knowledge?

For me, the lessons from the previous years were really good refreshers on how the heart works. As a second-grade teacher, I don’t really touch on human biology in my teaching. As it has been many, many years since I’ve taken a biology class, it was a great review of the circulatory system. This year, the concept of homeostasis was helpful in understanding the reasons behind animal adaptations.

B. How does the PhUn Week activity affect student interest in and enthusiasm for science?

My students were very excited about having a real life scientist not only visit, but also teach them. They were highly engaged in the hands-on activity, their excitement and interest in science was piqued, and this lasted beyond the visit. They have continued to talk about what they learned about homeostasis and animal adaptations. They recently made connections between their lessons about properties of matter and the insulating properties of animals’ blubber and birds’ feathers.

C. What is the benefit to the students in having a physiologist visit?

It’s helpful for students to meet people who spend their time working in the field of science. For early elementary students, science is often taught in short, fragmented lessons. When they have a scientist visit and lead an activity, it’s easier to understand the real world application of the lessons in science. It also may open their minds to future careers in the sciences. Physiologists, in particular, can be very relatable to young children because they can make connections to their own bodies and to the animals they are familiar with.

D. What is the benefit to the teachers in having a physiologist visit?

Fig. 3. Phizzy and Phreezy Bears. The stuffed animals Phizzy and Phreezy, are a popular addition used to elicit enthusiasm and help with the explanation of the lesson.

Fig. 4. Fun with Physiology activity book. The activity book was used to engage students in learning about the adaptations that polar bears have to stay warm in the winter.
It’s helpful to teachers to have a connection with a scientist, and to be able to refer to her at later times when discussing scientific concepts. It’s great to be able to step back and observe our students while they are learning from a visitor. It reenergizes us as teachers to see our students excited about learning and is helpful to see new ways to approach concepts and to facilitate hands-on activities.

DISCUSSION

Each year I return to this rural second-grade classroom, and we perform an exercise physiology experiment as part of PhUn Week. This past year, with some concern, I tried something new. I was unsure whether the students would understand the concepts of thermoregulation and homeostasis. Working with second graders (7–8 yr olds) can be challenging, so the key to success is to give examples that are familiar to them when adding new terms and concepts. Repeating the terms with familiar examples helps them to make connections. It is also typical that in each classroom there will be at least one disruptive student. The best approach to dealing with the disruptive behavior is to expect it and not to get off track. Making sure the students are not sitting and just listening for a long time is also important. This outreach session was only 1 h, with half of the time spent in hands-on activities. Short-term outreach sessions have been shown to increase students’ enthusiasm for science and benefit teachers with content review (11, 14).

When the students completed the experiment, they enjoyed keeping their results a secret until the entire class had finished. When the answer to the question, “Which mitt was the warmest?” was not unanimous, this gave the opportunity to reinforce the term adaptation and to point out that different animals have different adaptations that are successful. One student asked, “What about reptiles?” This was a fortuitous opportunity to describe how reptiles do not have adaptations to stay warm in the cold, and that they did not thermoregulate. Another student asked, “Then how do they get warm?” It was explained that lying on a rock in the hot sun during the day causes their body temperature to increase. This was followed by further explanation that, when the reptiles go back to their burrow, their body temperature drops all night. It was evident by the looks on their faces that the students understood the concept. The contrast of a mammal’s ability to thermoregulate and a reptile’s lack of ability to thermoregulate will be introduced earlier in the session when I return to the second grade next year. Ending the session with a class discussion of the students’ results helps to reinforce the concepts of thermoregulation, homeostasis, and adaptations.

Having a college student assist in the activities makes classroom management easier. Our new STEM Teaching Fellows program allowed me to bring in an undergraduate mechanical engineering student. We had two insulation bag experiments running at the same time so students did not have to wait long. He ran one set up and enjoyed working with the second graders. He stated after the activity, that he gained many valuable skills working with young students while also reviewing some fundamental science concepts. Including undergraduates in PhUn Week has been shown to reinforce their social responsibility by mentoring younger students and acting as role models (7). Undergraduates’ roles can be expanded by giving them the responsibility of creating a poster and presenting it at the PhUn Week networking breakfast session at the Experimental Biology meeting (7). Undergraduates report that they learn the material better by having to teach it to K–12 students (6). Providing them with the opportunity to talk about science to the lay public enhances their communication skills while increasing the science literacy of the K–12 students (23, 24).

Remembering to ask the teacher the benefits gained from the activities is important and an often-overlooked aspect of performing outreach. By allowing her time during the session to observe her students’ interactions with us was valuable, as she felt reenergized and learned new approaches for hands-on activities. This observation time is probably rare, as she is the lead instructor every day and her perspective of their learning is more traditional. By having this conversation with the teacher after the session, the physiologist can tailor future activities to fit the needs of both teacher and student. This information also provides some perspective for the physiologist as he/she plans the introductory and concluding discussions of the topic. As always, the greatest benefit of performing outreach is to increase science literacy among young people. While few will become scientists, all will need to be science literate to understand research findings reported in the news and medical concepts as adults. By returning to the same school, in the same grade, each year ensures that all of the students in the community are having the opportunity to meet and work with a scientist at a young age. Having a scientifically literate population will also increase their understanding of the need to support funding for research and advance our understanding as a society.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

P.A.H. conceived and designed research; P.A.H., C.H.F., and C.P. performed experiments; P.A.H. analyzed data; P.A.H. and C.P. interpreted results of experiments; P.A.H. and C.H.F. prepared figures; P.A.H. and C.P. drafted manuscript; P.A.H. edited and revised manuscript; P.A.H., C.H.F., and C.P. approved final version of manuscript.

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