



Community Partnership Designed to Promote Lyme Disease Prevention and Engagement in Citizen Science[†]

Veronica A. Seifert, Shane Wilson, Samantha Toivonen, Benjamin Clarke, and Amy Prunuske*
Department of Biomedical Sciences at the University of Minnesota Medical School, Duluth, MN 55812

The goal of this project is to promote Lyme disease prevention and to cultivate an interest in science through a citizen-science project coordinated by researchers at a public university and teachers at rural high schools. The lesson plan is designed to increase student interest in pursuing a science career through participation in an authentic research experience, utilizing a topic that has implications on the health of the surrounding community. Students are introduced in the classroom to zoonotic diseases transmitted by the *Ixodes* tick, the health risks of Lyme disease, and disease prevention strategies. Students then participate in a research experience collecting field data and ticks from their community, which are used in university research. To measure changes in student knowledge and attitudes toward Lyme disease and science careers, students completed surveys related to the learning objectives associated with the experience. We found participation in the activity increased student confidence and ability to correctly differentiate a deer tick from a wood tick and to recognize the symptoms of Lyme disease. In addition, students reported increased interest in pursuing a science degree in college or graduate school. Authentic research experience related to a disease relevant to the local community is effective at enhancing high school student engagement in science.

INTRODUCTION

Lyme disease is a tick-borne infection caused by the spirochete bacteria *Borrelia burgdorferi*, harbored within the deer tick, *Ixodes scapularis*. Though Lyme disease is found worldwide and in most states in the United States, there is a higher prevalence in the Northeast and Upper Midwest including the local community where our University is situated (6). In the US, only the *Ixodes scapularis* is capable of transmitting *Borrelia* to humans, so it can be beneficial for individuals to be able to distinguish between tick species. Early signs of *Borrelia* infection include fever and flu-like symptoms, as well as erythema migrans, a characteristic bulls-eye rash around the tick bite. If detected early, antibiotics can treat Lyme disease; however, if left untreated, the infection may become systemic, leading to more severe complications, such as arthritis, carditis, and meningitis. To prevent infection, it is important to prevent tick bites, to frequently check for ticks, and to be promptly treated if exhibiting symptoms after an *Ixodes* bite.

Science and math are stumbling blocks for many individuals; in the US, student scores are significantly lower in these areas than they are in other countries (11). However, these skills are in high demand due to the environmental, medical, and technological challenges that we face as a global community. Meeting these needs requires a greater number of individuals with degrees in science, technology, engineering, and math (STEM) (17, 18). Science education often emphasizes discrete facts rather than the problem-solving skills needed to address real-world challenges (16). Yet studies have shown that students are more apt to have greater learning gains when they study material that is personally relevant and involves authentic research (1, 3). Experimental aspects of research are not easily incorporated into secondary education models, so we propose a collaborative partnership between educational institutes of research and rural high schools, focused on education about Lyme disease.

The Lesson on Lyme Disease attempts to overcome barriers to understanding science and to engage students in higher-order thinking by adopting multiple theories on education and learning that emphasize modeling (2), structured knowledge (5), and authentic learning (4) through a citizen science project. The lesson incorporates inquiry-based learning (IBL), which requires students to construct knowledge through experience and emphasizes the learning process rather than facts (12). IBL is a process that scientists

*Corresponding author. Mailing address: 321 Medical School Duluth, 1035 University Drive, Duluth, MN 55812. Phone: 218-726-6748. Fax: 218-726-7906. E-mail: amy.prunuske@gmail.com.

†Supplemental materials available at <http://jmbe.asm.org>

use regularly in the laboratory and are well-equipped to facilitate with students.

Scientists are being encouraged, and are even expected, to engage in community outreach (7), but particular segments of the population, especially in rural areas (<20,000 people) are much less likely to have interactions with scientists. Scientist visits to the classroom have the potential to dispel certain stereotypes students may have about scientists' careers that may limit their desire to pursue a STEM degree, while also providing students with a first-hand account of scientific concepts, skills, and relevance (9, 13). Therefore a goal of our intervention was to determine whether participation in the activity impacted students' interest in science and pursuing a science degree in college.

Providing education about Lyme disease and *Ixodes* ticks through a citizen science outreach program not only allows for extensive sample collection of ticks, which can benefit the research aims of understanding the distribution of the pathogen, it also provides the public with a personal investment into research relevant to their own health and the health of their community. When people are involved in the scientific process, as they are in citizen-science projects, there is a heightened appreciation for the value of science and scientific-inquiry in society.

Intended audience

The activity was developed for use with high school students and implemented in rural high schools, a tribal school, and a correctional facility. The activity could be adapted for application with younger students, undergraduates, or an adult education program. A graduate student led the activity, which included a one-hour interactive presentation followed by at least one hour of fieldwork (Appendix 1). The lesson was implemented in an area of Minnesota known to have a high prevalence of Lyme disease. Even in an area that reportedly does not have a high prevalence of Lyme disease, this activity could be modified to address a number of other tick-borne illnesses.

Prerequisite knowledge

Prerequisite knowledge was provided in a presentation at the beginning of the lesson. Some prior exposure to microbiology and ecology, including the transmission of infectious diseases, would be beneficial but is not necessary.

Learning objectives

At the completion of this activity, students will be able to:

1. Differentiate between a deer tick and wood tick
2. Describe symptoms associated with Lyme disease
3. Identify strategies to prevent Lyme disease
4. Collect field data
5. Develop hypotheses to solve a problem

6. Explore pursuing a science degree in college or graduate school

PROCEDURE

Materials

Global positioning system (GPS) device
 Tick repellent (diethyltoluamide-DEET, permethrin)
 Tick drag cloth (Appendix 1)
 Ziploc bag containing "Tick Kit" for collecting ticks in the field:

- Tick data sheet (Appendix 3)
- Tick ID cards (<http://www.health.state.mn.us/divs/idepc/dtopics/tickborne/card.html>)
- Tweezers
- Lab gloves
- 1.5-milliliter (mL) Eppendorf tubes containing isopropanol or ethanol hand sanitizer
- Markers
- Pens

Part 1. The lecture. The introductory presentation (Appendix 2) highlights Lyme disease transmission and prevention, *Borrelia burgdorferi* and tick ecologies, Lyme epidemiology, practices for capturing ticks, the scientific method, and how to conduct a field survey. Students are also trained to differentiate between *Ixodes scapularis* and the wood tick *Dermacentor variabilis*. The presentation should take about one hour and can be adjusted to fit to one class period.

Instructors are encouraged to interact with students during the presentation by finding out whether they know someone affected by Lyme disease and asking them to give examples of symptoms of Lyme disease, to discuss why the research might be important, to identify strategies to collect ticks, and to discuss why we might want to capture information about terrain, time of day, and season during the tick collection. Students are required to reflect on the scientific method as well as develop their own hypotheses for capturing ticks and assessing the risk of Lyme disease in their area.

Part 2. Fieldwork. Students are then divided into groups of three or four, and each student is assigned a job that contributes to the team effort of collecting ticks and field data. During the presentation, students formulate strategies to collect ticks. Prior experimentation has shown that drag sampling is effective, and at least one group should conduct sampling by this method (8). To make a drag cloth, a square meter of white, nappy fabric is attached at one end to a stick, and lead sinkers are secured to the other end to ensure the cloth drags on the ground (Fig. 1). The string makes it easier for students to drag the cloth without having to bend down as they walk along transects. Each group is also provided a tick kit, which contains the tick ID card, data collection sheet, tweezers, lab gloves, 1.5-mL Eppendorf tubes filled with hand sanitizer, a marker, a GPS device,

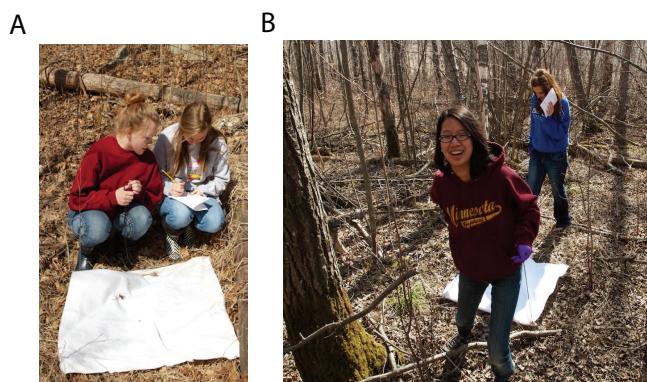


FIGURE 1. Examples of students conducting the fieldwork in woods near their high school. Drag cloth on the ground (A) and in use (B).

and tick repellent such as DEET or permethrin. Students should wear long pants while collecting the ticks, apply a tick repellent, and check for ticks at the end of the activity.

Students can conduct the fieldwork in any grassy area around the school or as part of a field trip. Ideal habitats for ticks are grassy areas bordered by woods. One student is designated “the dragger” and walks along a 100-meter transect dragging the “drag cloth” on the ground. This maintains consistency in height and speed of the collection method, thereby limiting experimental variability. The cloth should be low to the ground in the hopes of nabbing questing ticks. Students should check for ticks every 10 meters, along multiple 100-meter transects. Another student is assigned as “the collector,” helping locate ticks on the cloth and picking them off. The collector wears gloves and uses tweezers to place the ticks in the Eppendorf tube. If more than one tick is found in an area of grouped transects, they may all be placed in one tube. Students should use the tick ID card to distinguish deer ticks from wood ticks, life stage, and gender. Female *Ixodes scapularis* and nymphs are known to carry *Borrelia burgdorferi* and are therefore the most important for the Lyme researchers, but depending on the students’ interests, there may be value in preserving all of the ticks. The collector reports how many ticks are gathered at each stop, the type of tick, life stage, and gender to another student in the group “the recorder.” The recorder enters this information onto the survey sheet (Appendix 3), as well as the date, time, and place (city location or GPS location). Finally, the group should measure and record any other variables the class thinks might be important, such as weather, temperature, and terrain, including specifics on the flora, fauna, and soil. Students should try to collect ticks for at least one hour. Additional collecting after the class period can be done at the discretion of the instructor and depending on the hypotheses generated during the in-class session.

Part 3. A day of science: Science opportunities at the university. A final component to this collaboration involves inviting classes to tour the lab facilities where the

ticks are analyzed. Giving students an opportunity to tour the university facilities provides a basis of familiarity that may increase student confidence about pursuing a science major during college. As part of the Science Day Experience, students have also attended a show at the Planetarium, interacted with the Geology Department Club, participated in a human anatomy lesson with plasticized limbs in the Medical School, and viewed detailed surface anatomy of the tick under the microscope and fluorescent *Borrelia burgdorferi* using confocal microscopy. The visit is also an informal opportunity for students to meet and talk with graduate students, faculty, and staff from different science departments to learn about pursuing professional degrees and science careers.

Safety issues

Recruiting students to collect deer ticks that may carry the bacteria that cause Lyme disease does pose a risk that the students will be bitten by a tick and become infected with a tick-borne illness. Participation in the activity is voluntary, and we recommend minors’ parents complete a consent form prior to the students participating in the activity (Appendix 5). Even if a student does not directly participate in the activity, they will benefit from hearing the interactive presentation and helping to generate hypotheses. The activity will educate students about how to safeguard against Lyme disease since students will be required to take appropriate safety measures during the fieldwork including dressing in long pants to prevent ticks from attaching to their skin, applying a tick repellent, and learning to do daily tick checks. Students learn proper tick removal technique by slowly pulling an attached tick using tweezers and will never directly touch the ticks since gloves are worn. Individuals wearing permethrin-treated socks and shoes resulted in 75% fewer tick bites than individuals wearing untreated items, and applying DEET to exposed skin minimizes the risk of infection (14).

RESULTS

As part of a partnership between the university and local high schools, a master’s student gave an interactive presentation on Lyme disease, encouraging students to devise their own strategies for the collection of the ticks. In groups, students then completed fieldwork to collect ticks and recorded relevant field data such as ecological terrain, weather, time of day, tick species collected, and GPS coordinates (Appendix 3, Fig. 1). The tick samples were used for the master’s student’s thesis project, which involved improving characterization of the risk of exposure to *Borrelia burgdorferi* in the Upper Midwest. To facilitate familiarity with post-secondary STEM opportunities, some of the students attended a Day of Science to visit the place where the graduate research took place and witness how the samples and data would be used for authentic scientific research. In addition, students and community members

can continue to follow the Lyme research through a website developed by an undergraduate <http://d.umn.edu/lyme/>.

Over 2,000 students at nine different educational facilities and at two public forums participated in the “Lesson on Lyme disease” and the tick collecting. A total of 170 ticks from approximately 40 different locations have been submitted as part of the project, and from these ticks, the researchers have been able to culture a novel Minnesota strain of *Borrelia burgdorferi* to use in their research.

Survey assessment

A survey was given to students at three schools to establish the baseline knowledge and science attitudes of the students prior to participation in the activity (Appendix 4). Students from one of the schools took the same survey a day after the field experience. Survey data were de-identified. Pre and post survey data were matched up by student-chosen code names including the first two letters of the student’s last name followed by a favorite food (example: NeTaco). Descriptive statistics were calculated in Excel and significance between the pre and post surveys was calculated with the statistical software JMP www.jmp.com/en_us/home.html using a paired *t*-test. Two researchers independently coded the open response survey questions for important themes. This study was approved by the University of Minnesota IRB 1309E42103.

Survey findings

Two hundred nineteen students from three different rural high schools completed the pre-activity survey. We used the survey to establish the students’ level of comfort with our learning objectives before participating in the activity. We found that students from all three high schools had low confidence in their ability to differentiate between a deer tick and a wood tick, had low awareness of how to prevent Lyme disease and its associated symptoms, and were interested in going to college and graduate school but not necessarily pursuing a science degree (Table 1). We resurveyed a subset of these students to report their confidence on the learning objectives after the activity (Fig. 2). Specifically, students reported increased awareness of the symptoms associated with Lyme disease, of how to prevent Lyme disease, and of how to correctly identify a deer tick. We also found that, after participating in the activity, students had an increased desire to pursue science in college and in graduate school. Thus, the pre-activity and post-activity surveys indicate that the activity meets its primary learning objectives.

It is possible that students who reported on the survey that they could differentiate ticks might not actually be able to perform the task. During the presentation, students were provided a small vial of wood ticks and a certain number of deer ticks suspended in hand sanitizer and were asked to identify how many deer ticks were contained within the vial.

They also got practice doing this task during the field experience, but it was difficult to assess their individual skill at this point, because they were working as a group. Therefore, on the post-activity survey, students were given pictures of a deer tick and a wood tick and asked to circle the deer tick. Eighty three percent of the students correctly circled the deer tick, suggesting that the majority of the students were able to successfully differentiate between the two types of ticks after participating in the activity.

The general open-response feedback from participants was extremely positive. Students enjoyed learning about ticks and wanted to know more about Lyme disease and ticks after the presentation. Students felt the activity was valuable because “...I felt that I was helping people accomplish something ...”. It also changed some of the students’ attitudes toward the ticks. “I had a lot of fun... Looking for ticks and being able to see them without being scared.” In addition, the students liked being part of the scientific process and being engaged in hands-on learning. Even students who did not collect any deer ticks during the activity were excited to come up with strategies to increase tick yield in the future. The students generated a number of ideas, including changing the dragging technique, altering the drag cloth shape or material, using locals to identify where to drag, or identifying a chemical that would attract ticks (Table 2).

Student attitudes toward science contribute to retention and enrollment in science courses. Students completed a modified Attitudes Toward Science Inventory (10) to assess student feelings toward science. The items students rated most highly indicated that students feel science is important for a country’s development and for understanding the natural world. However, the data also show that students were less likely to agree that “knowing science is important in order to get a good job” and “I like the challenge of science assignments.” (Fig. 3). Overall, student participation in authentic science research as citizen scientists met the objectives of increasing awareness about Lyme disease, allowing students opportunities to engage in hypothesis generation, and encouraging students to consider pursuing science degrees.

DISCUSSION

Authentic engagement in research is a noteworthy method for enhancing student understanding of STEM topics and to introduce students to multiple scientific disciplines. This study outlines a project designed to promote disease prevention and to cultivate an interest in science through a citizen science project between a public university and area high schools. Research aimed at monitoring Lyme disease in deer ticks in Northern Minnesota is incorporated into high school classrooms, where students are introduced to the life cycle and the health risks of Lyme disease and encouraged to generate their own hypotheses to test while participating in the collection of field data on ticks. The primary goal of this lesson is to increase student interest and understanding

TABLE 1.
Student agreement with the learning objectives before participating in the activity.

	School 1 n=23	School 2 n=75	School 3 n=177
I can correctly identify a deer tick from a wood tick	2.96±1.55	2.60±1.11	3.24±1.36
I am aware of symptoms associated with Lyme disease	3.13±1.29	2.16±0.97	2.69±1.06
I am aware of how to prevent Lyme disease	3.00±1.24	2.04±1.02	2.33±1.04
I am interested in participating in scientific research	4.02±0.86	3.22±1.12	2.79±1.09
I am interested in going to college	4.65±0.77	4.62±0.72	4.15±1.11
I am interested in pursuing science in college	3.39±1.20	3.03±1.28	2.56±1.30
I am interested in going to graduate school	4.5±0.84	4.00±1.24	3.52±1.35
I am interested in pursuing science in graduate school	3.02±1.22	2.91±1.20	2.33±1.26

1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

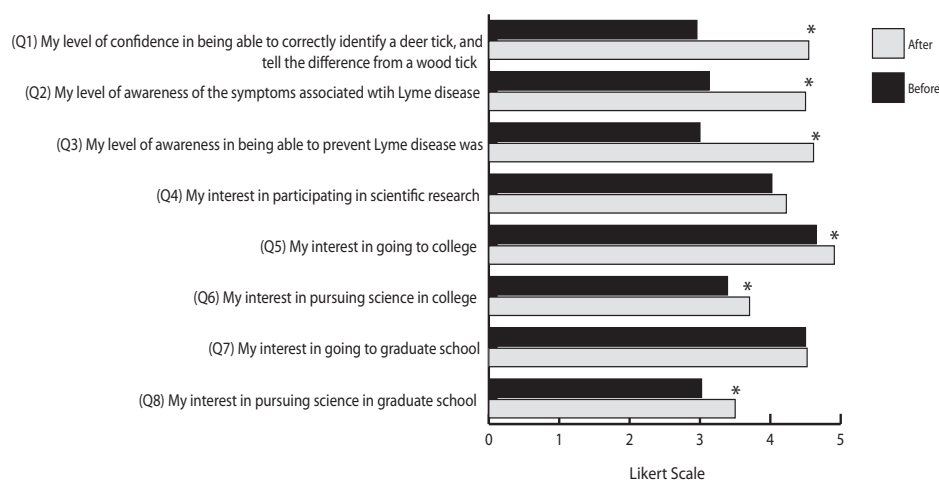


FIGURE 2. Student-reported ability to achieve the learning objectives before and after participation in the activity. Students were asked to rate their agreement with several statements (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). The students' answers were averaged. *Indicates a statistically significant difference with a p value < 0.05.

TABLE 2.
Student-generated hypotheses to increase tick yield.

1. "I think that the ticks would be easier to collect if we didn't potentially knock them off the grass, so maybe putting a drag in front of ourselves???"
2. "I thought that maybe the sheets should be longer. Not wider, but longer. This is because when you first drag the cloth you may disturb the tick, but it might not latch on right away. By dragging a longer cloth, you might have a better chance of getting a tick."
3. "...coveralls rather than a drag."
4. "Having a complete outfit of the fiber they stick to."
5. "Maybe ask locals where they have had a lot of ticks. Thus helping your chances of getting deer ticks. Maybe do collecting in tall grass fields."
6. "Pursue the idea of the waders / some kind of attraction on your legs as you're walking because no matter what you'd get ticks on your legs, so why not be able to catch them easier?"

of science through an inquiry-based research experience with science practitioners. Learning about Lyme disease also provides a public health platform to arm students with awareness of the implications of the illness and methods of prevention. This model allows for meaningful integration of the community with university researchers (Fig. 4).

The results of our surveys suggest student participation in authentic research positively impacted student interest in science and understanding of Lyme disease. It is important to incorporate science lessons that involve inquiry because, when students participate in IBL, their self-efficacy about how to do science is increased. This type of experience is especially important at the high school level, where the rote memorization of facts is often the predominant form of learning, and students show decreased interest in science (15). Students reported on our surveys that the "hands-on experiences are the most interesting" and often expressed a desire to continue contributing to the research, for which we could provide them additional tick collection kits. Students also indicated a lack of information on the routes to

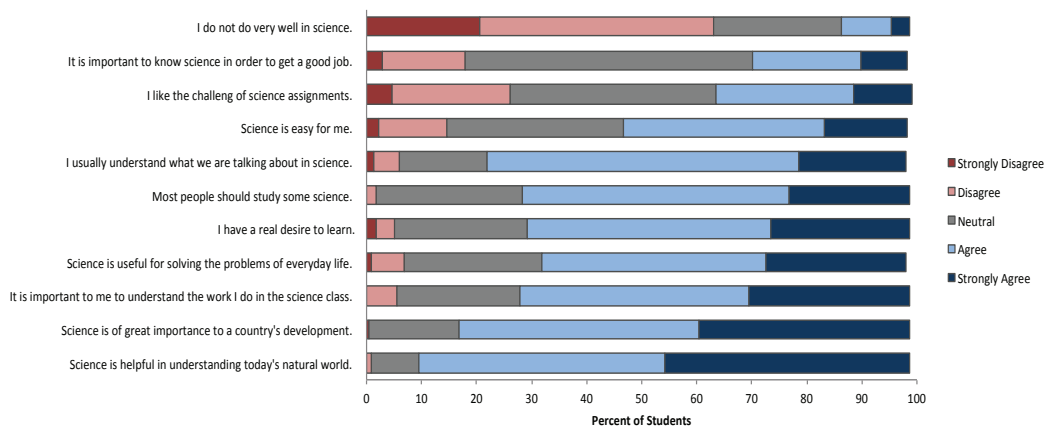


FIGURE 3. Science attitudes were collected from students participating in the Lesson on Lyme using the Modified Attitudes Toward Science Inventory. Students from three different high schools ($n = 219$) used a Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) to indicate their agreement or disagreement with each of the statements. The graph shows the percentage of students selecting each of the categories.

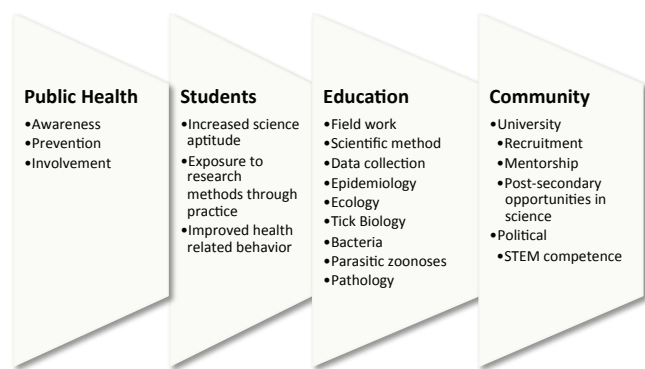


FIGURE 4. Model of constituents benefitting from Lyme outreach partnership.

professional science careers and what those careers entail: "How do you become a scientist? ...I know you go to college but what about after?" These reflections reinforce the idea that most students are not exposed to contextualized applications of science prior to attending college. Teachers also appreciated the scientists' visits to the classroom and went on to adapt this lesson into their ongoing curriculum, building their own as well as their students' comfort with IBL (19).

In developing the PowerPoint presentation, there were questions that frequently arose, and the lesson was constantly evolving based on student and high school teacher feedback. Engaging students in developing their own hypotheses about why Lyme disease affects individuals in certain areas as opposed to others, about how to collect ticks, and about how to use information about climate, time of day, season, and ecological factors are key to students practicing the scientific process. In addition, this type of experience can also help researchers refine their own thinking about the topic through the incorporation of diverse points of view. Students' confidence was enhanced in their ability to act as

scientists with a sense of ownership in the direction of the research. Fieldwork is not always successful in the collection of specimens, but this serves as a lesson in the importance of persistence and the need to constantly evaluate methods to optimize experimental outcomes. Thus, the project was designed using both the contributory and collaborative models of citizen science (7).

Future directions

It is important to look at long-term effects of science outreach in high school classrooms. Long-term surveys following students into their college careers after exposure to citizen science research would be a valuable measure of the overall success of this approach. Follow-up is important in order to establish whether health information related to Lyme disease is retained and whether the intervention altered behaviors by encouraging students to engage in tick checks and to use insecticides. Maintaining partnerships with teachers and the community will produce more information on how to enhance student confidence and interest in science while facilitating the dissemination of science research and important public health information.

SUPPLEMENTAL MATERIALS

- Appendix 1: Lesson plan
- Appendix 2: PowerPoint presentation
- Appendix 3: Data collection sheet
- Appendix 4: Surveys
- Appendix 5: Consent form for parents

ACKNOWLEDGMENTS

The authors wish to acknowledge the following funding sources: Pathways to Advanced Degrees in Life Sciences grant (GM-086669) to BC, start-up funds from the University of

Minnesota to AP, and Undergraduate Research Opportunities Program grants to SW and ST. Some results were previously presented at the Research for Indigenous Community Health symposium, August 2014, and the Society for the Advancement of Biology Education Research Meeting, July 2015.

Special thanks to Chris Evavold and his students at Esko High School, Tim Strasser and his students at Eveleth High School, and Don Polkinghorn and his students at Superior High School! Finally, thanks to the additional staff and community members who allowed VS to deliver this lesson to students at Cloquet High School, Duluth Public Schools, Fond du Lac Ojibwe Schools, Riverwatch Congress, Thistledeew Correctional Facility, and Wild Ones –Arrowhead chapter. The authors declare that there are no conflicts of interest.

REFERENCES

1. **American Association for the Advancement of Science.** 2011. Vision and change in undergraduate biology education: a call to action. Washington, DC.
2. **Bandura, A.** 1977. Social learning theory. General Learning Press, New York, NY.
3. **Bransford, J., A. L. Brown, and R. R. Cocking.** 1999. How people learn: brain, mind, experience, and school. The National Academies Press, Washington, DC.
4. **Brown, J. S., A. Collins, and S. Duguid.** 1989. Situated cognition and the culture of learning. *Educ. Res.* **18**(1):32–42.
5. **Bruner, J.** 1996. The culture of education. Harvard University Press, Cambridge, MA.
6. **Centers for Disease control and Prevention.** Reported cases of lyme disease. [Online.] www.cdc.gov/lyme/stats/index.html.
7. **Dickinson, J. L., et al.** 2012. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers Ecol. Environ.* **10**:291–297.
8. **Falco, R. C., and D. Fish.** 1992. A comparison of methods for sampling the deer tick, *Ixodes dammini*, in a Lyme disease endemic area. *Exp. Appl. Acarol.* **14**(2):165–173.
9. **Fitzakerley, J. L., M. L. Michlin, J. Paton, and J. M. Dubinsky.** 2013. Neuroscientists' classroom visits positively impact student attitudes. *PLOS One.* **8**(12):e84035.
10. **Gogolin, L., and F. Swartz.** 1992. A quantitative and qualitative inquiry into the attitudes toward science of nonscience college students. *J. Res. Sci. Teach.* **29**(5):487–504.
11. **Kelly, D., H. Xie, C. W. Nord, F. Jenkins, J. Y. Chan, and D. Kastberg.** 2013. Performance of US 15-year-old students in mathematics, science, and reading literacy in an international context—first look at PISA 2012. National Center for Education Statistics. [Online.] <http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2014024>.
12. **Komoroske, L. M., S. O. Hameed, A. I. Szoboszlai, A. J. Newsom, and S. L. Williams.** 2015. A scientist's guide to achieving broader impacts through K–12 STEM collaboration. *BioScience* **65**(3):313–322.
13. **Laursen S., C. Liston, H. Thiry, and J. Graf.** 2007. What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K–12 classrooms. *CBE Life Sci. Educ.* **6**:49–64.
14. **Miller, N. J., E. E. Rainone, M. C. Dyer, M. L. Gonzalez, and T. N. Mather.** 2011. Tick bite protection with permethrin-treated summer-weight clothing. *J. Med. Entomol.* **48**(2):327–333.
15. **National Academies of Sciences.** 2012. Monitoring progress toward successful K–12 STEM education: a nation advancing? The National Academies Press, Washington, DC.
16. **National Research Council.** 2012. A framework for K–12 science education: practices, crosscutting concepts, and core ideas. [Online.] www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.
17. **National Science Board.** 2014. Revisiting the STEM workforce, a companion to science and engineering indicators. National Science Foundation. [Online.] www.nsf.gov/nsb/publications/2015/nsb201510.pdf.
18. **PCAST.** 2010. Prepare and inspire: K–12 education in science, technology, engineering, and math (STEM) for America's future. President's Council of Advisors on Science and Technology, Washington, DC. [Online.] www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf.
19. **Scott, H. C.** 2013. Inquiry, efficacy, and science education. Ph.D. dissertation. Georgia Southern University, Statesboro, GA.