01 Mar 2016

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David J. Westenberg
Missouri University of Science and Technology, djwesten@mst.edu

JOURNAL OF MICROBIOLOGY & BIOLOGY EDUCATION, March 2016, p. 29-31
DOI: http://dx.doi.org/10.1128/jmbe.v17i1.1043

The Engaged Microbiologist: Bringing the Microbiological Sciences to the K–12 Community

David J. Westenberg
Department of Biological Sciences and Department of Chemical and Biochemical Engineering, Missouri University of Science and Technology, Rolla, MO 65409

Exposing K–12 students to cutting edge science that impacts their daily lives can bring classroom lessons to life. Citizen-science projects are an excellent way to bring high-level science to the classroom and help satisfy one of the cornerstone concepts of the Next Generation Science Standards (NGSS), "engaging in practices that scientists and engineers actually use." This can be a daunting task for teachers who may lack the background or resources to integrate these projects into the classroom. This is where scientific societies such as the American Society for Microbiology (ASM) can play a critical role. ASM encourages its members to engage with the K–12 community by providing networking opportunities and resources for ASM members and K–12 teachers to work together to bring microbiology into the classroom.

INTRODUCTION

The general public is becoming aware of how microbiology touches every aspect of our lives. Microbes are rising within the public consciousness in the form of stories and reports on topics such as new and emerging diseases, the microbiome, probiotics, and microbes on a variety of surfaces. As interest in how microbes impact our health and environment grows, microbiologists have a golden opportunity to share our passion with the public, especially the K–12 community, and inspire future generations of scientists. Discussions of the science behind the headlines provide an approachable introduction to science and ethics for students and an opportunity to engage in meaningful dialogue. Citizen-science projects inspire students to ask meaningful questions about the world around them and draw the K–12 community into actively participating in science rather than passively learning. The microbiology community should be prepared to engage these inquiring minds. This citizen-science themed issue of *JMBE* is an ideal opportunity to put into perspective the opportunities available through ASM to involve membership in outreach and education, particularly K–12 education.

ASM AND K–12 OUTREACH OPPORTUNITIES

For over 40 years, the Education Board of the American Society for Microbiology (ASM) has addressed the educational needs of society members, but it is over the past 25 years that the Board has grown into a leading force in biology education (2). The board has now grown to serve the "K to Gray" education audience by addressing K–12, undergraduate, graduate, medical and international students, teachers, and researchers. The diverse offerings of professional development programs, mentoring programs, fellowships, meetings and journals have enabled ASM to support microbiology educators at every level of education, including informal education. ASM participation in informal education such as science fairs, festivals, and other opportunities for face-to-face interaction opens learning opportunities not only for students who want careers in biology but also for the general public.

One of the audiences more recently addressed by the ASM Education Board is the K–12 community. The Committee on K–12 Outreach was established in 1994 as the Precollege Education Committee to encourage the use of microbiology activities in the K–12 classroom. Some of the early activities of the committee included running Microbial Discovery Workshops and Teacher Science Day events that partnered K–12 teachers and scientists in developing and using curriculum resources. The stated mission of the committee is to engage the community of microbiologists and educators in K–12 outreach and promote microbiology in the K–12 community.

To accomplish these goals, the committee provides professional development programs at nationally sponsored teacher meetings each year. It has also worked to promote interest in microbiology careers through career resources targeted toward high school students, such as careers posters, and raising awareness and accessibility of materials to the K–12 community. The committee provides materials for K–12 outreach and encourages the development of peer-reviewed

Corresponding author. Mailing address: 400 W. 11th Street, Rolla, MO 65409. Phone: 573-341-4798. Fax: 573-341-4821. E-mail: djwesten@mst.edu.

activities for the K–12 community. It also encourages partnerships with other professional societies, government agencies, and foundations and recruits and engages volunteers for K–12 community activities. To support involvement of the microbiology community in K–12 education, the committee sponsors presentations at conferences such as the American Society for Microbiology Conference for Undergraduate Educators and provides standardized presentations and guidelines on outreach for members. Through all of these activities, the committee works to increase recognition of microbiology as an integral part of scientific literacy by promoting the adoption of national science standards and encouraging the incorporation of microbiology in science curriculum standards as model systems for teaching basic biological principles. The result is to emphasize the important role of microbes in all subjects.

ASM COMMITTEE ON K–12 OUTREACH ACTIVITIES AND ENGAGEMENT

The ASM Committee on K–12 Outreach provides opportunities and materials for ASM members to interact with the K–12 community. The committee organizes research symposia at the annual meetings of major science education organizations such as the National Association of Biology Teachers and the National Science Teachers Association. The purpose of these symposia is to provide scientific content for K–12 teachers and promote interaction between ASM members and the education community. Examples of recent symposia themes include "Microbes at Work," "A Taste of Microbiology," "Microbes and Space Flight," and "Extreme Microbes." These sessions bring in leaders in the field who provide scientific content to educators to stimulate their interest in the topics and encourage development of hands-on activities that get students actively engaged with the topic.

To facilitate active learning, the committee oversees a rich collection of hands-on activities which are solicited from the education and scientific communities (www.asm.org/classroomactivities). These activities are great not only for bringing the microbial world into science courses but also for community-based events and other programs for the general public. All activities come from classroom teachers and microbiologists and have been used in the classroom setting. Each activity is peer reviewed for scientific and educational content, active learning and engagement, alignment with science education standards, and clarity of accompanying instructions regarding performance and safety. Each activity includes background material, material lists, detailed instructions, and guidelines for extensions for various target audiences. The goal is to make the activities classroom ready for educators to use in their classrooms. ASM members are encouraged to use these activities for classroom visits and other outreach opportunities or as supplemental activities to encourage participation in, or as follow-up activities to, citizen-science projects.

CITIZEN SCIENCE AND ACTIVE LEARNING IN THE K–12 COMMUNITY

Citizen-science projects present an ideal opportunity for microbiologists to educate the K–12 community. What better way to excite students about the importance of microbiology than through participating in generating valuable data to support microbiology research? Engaging students in citizen-science projects can then serve as a springboard to launch students into science and technology. The challenge for many educators is often finding a way to fit participation in citizen-science projects into their already packed curriculum. Fortunately, the Next Generation Science Standards (6) have been developed in such a way as to allow teachers the flexibility to decide the appropriate model system to use to address the core concepts. A vast array of resources and case studies is available for teaching these concepts using microbiology, including the National Center for Case Study Teaching in Science (http://sciencecases.lib.buffalo.edu/cs/) and hands-on activities such as those available through ASM. Once the basic concepts are introduced, students can then participate in community science programs such as CyanoWatch (www.cyanotracker.uga.edu/index.html), Plankton Project (www.planktonportal.org/), or World Water Day (www.unwater.org/worldwaterday). A great place to start when searching for a citizen-science project is the SciStarter website (http://scistarter.com/finder). Citizen-science projects typically involve having members of the community collect data or make observations that they submit through a website. Participation by the community provides the scientific community with data from diverse sources, including distant locations or populations that vary in age or other demographic factors. Participants benefit from learning how science is done, how data are collected and how they are analyzed. Participation in citizen-science projects is often free but may involve purchasing a test kit or other resources. From the microbiology perspective, the diversity of projects available results in engagement that leads the participant beyond the obvious topics in the news, such as infectious diseases like Ebola, measles, HIV, and influenza, to global topics such as climate change, renewable energy, sustainable agriculture, and nutrition. Microbiologists can utilize these tools to help stimulate inquiry and educate the K–12 community regarding the significance of their projects. For example, a student can first learn about microbes in the gut through an activity such as "Bacteria that help and hurt cows" or "What makes flatulence," which are available on the ASM Education website (www.asm.org/index.php/educators/K-12-classroom-activities). They can then participate in a gut microbiome project, such as the American Gut Project (http://americangut.org), in which they can learn about their own microbiome and compare their results to those of others of the same or different ages, the same or different locations, or other variables. As participants learn about themselves they are also generating valuable data for the researchers.

MICROBIOLOGY AND THE NEXT GENERATION SCIENCE STANDARDS

The Next Generation Science Standards are built on a framework established by the National Research Council Report called "A Framework for K–12 Science Education: *Practices, Crosscutting Concepts, and Core Ideas"* (5). This report, based on science education research, identifies the core concepts and encourages teaching science "by engaging in practices that scientists and engineers actually use." The American Society for Microbiology is a strong supporter of science, technology, engineering, and mathematics (STEM) education and rigorous common state standards in mathematics and science. As stated by the STEM Education Coalition (www.stemedcoalition.org/), "STEM education is closely linked with our nation's economic prosperity in the modern global economy; strong STEM skills are a central element of a well-rounded education and essential to effective citizenship" (7). Microbiology touches every aspect of our lives, and important decisions that impact our health and environment depend on a well-educated public. ASM supports the development of rigorous mathematics and science curricula and encourages the use of microbiology as an accessible approach to developing instructional materials to address key STEM concepts and skills.

Incorporating microbiology into the K–12 classroom is an accessible approach to developing instructional materials to address the key STEM concepts and skills outlined in the framework. For example, the five key Life Sciences topics in the Next Generation Science Standards (Natural Selection and Evolution, Structure and Function, Inheritance and Variation of Traits, Matter and Energy in Organisms, and Ecosystems, Interdependent Relationships in Ecosystems) parallel the core concepts promoted by the American Society for Microbiology Curriculum Guidelines (Evolution, Cell Structure and Function, Information Flow and Genetics, Metabolic Pathways, Microbial Systems, and Impact of Microorganisms) (4), which are based on the Vision and Change in Undergraduate Biology Education Core Concepts (1). Educators seeking engaging ways to teach the five key topics can look to microbiology for relevant, topical, easy-to-use examples. Microbiology-related citizen-science projects can reinforce these lessons by engaging K–12 students in the scientific process, leading to dialogue on the significance of each project and their impact on society. Such discussions are great opportunities to engage students with geography, history, and social sciences. Mathematics and statistics are valuable tools for all microbiologists, and these subjects can be readily integrated into the curriculum through examples in microbiology using the data generated through citizen-science projects.

SUMMARY

STEM education is the backbone of the American economy (8), and job growth in STEM fields will require more young people to seek degrees in the STEM disciplines. What better way to encourage young people than to get them engaged in science from an early age through participation in meaningful and relevant science projects? Citizen science is the perfect entryway for young students, and even their entire family, into the benefits of STEM education. Formally, the Next Generation Science Standards have established a framework for science education, and a critical element of this framework is the focus on science and engineering practices and not just specific content. Teaching based on these standards promotes inquiry, problem-solving and other forms of active learning that have been shown to improve student performance and retention in STEM education (3). We encourage everyone to explore new ways to teach core biology concepts by using the power of the microbes that live in and around us.

ACKNOWLEDGMENTS

The author would like to thank the staff and leadership of the ASM Education and Communications Departments for their support and guidance, especially Neil Baker, Amy Chang, Kelly Gull, and Erika Shugart. The author declares that there are no conflicts of interest.

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