SPORE* SERIES WINNER

Facilitating Scientific Investigations and Training Data Scientists

Students and teachers have free online access to an electron microscope in order to explore the world of insects.

Michele A. Korb[1]† **and Umesh Thakkar**[2,3]†

On a Monday morning in Pittsburgh, Pennsylvania, 29 sixth-grade students and their teacher conducted scientific investigations on insect adaptations by remotely controlling an environmental scanning electron microscope from their classroom. Before the session, these students gathered and mailed insect specimens to the Beckman Institute of the University of Illinois at Urbana-Champaign, where the electron microscope is physically located. Like any principal investigator, their teacher submitted a formal proposal to request access to the microscope for a classroom project (*1*). The proposal was to participate in the Beckman Institute's Bugscope, http://bugscope.beckman.illinois.edu, a free educational technology outreach project, which enables kindergarten to 12th grade (K–12) and undergraduate students and teachers to remotely access and control the microscope in real time from their classroom computers. For the teacher, the educational benefits to her students included the ability to see insect anatomy details too minute for their classroom microscopes; the development of the skills necessary to acquire their own images; and, most important, the opportunity to chat with scientists and ask them questions about insects, electron microscopy, and science careers.

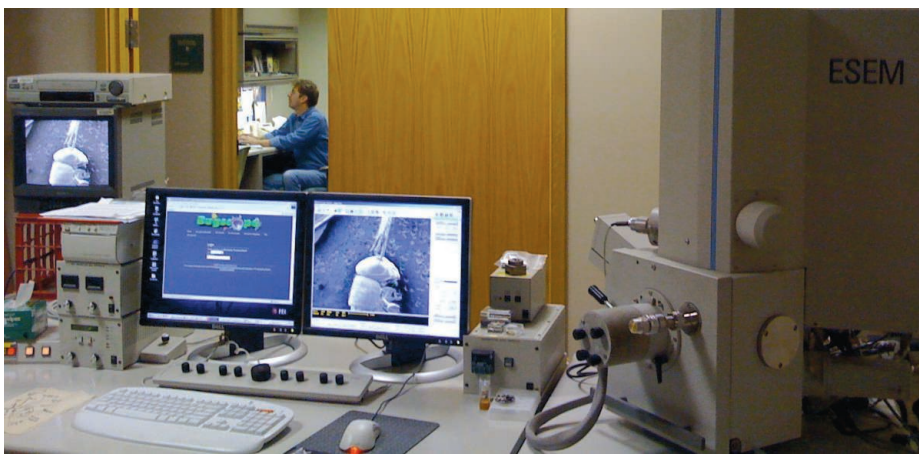
There is growing interest in providing learning opportunities via the cyberinfrastructure (*2*). A National Science Foundation (NSF) report defined "cyberlearning" as "learning that is mediated by network computing and communication technologies" [p. 10 in (*3*)]. The report also suggested that, for students and teachers to learn how to author, publish, and curate data, they must acquire the skills of data scientists (see the first figure).

Bugscope hosted its first session in March 1999 (*4*). Since then, there have been 580 classroom sessions with 415 schools (106 of those being repeat participants) during which students and teachers have acquired 120,000 images (*5*). These sessions represent classrooms across K–12 grades and also occur in informal settings, such as libraries and museums, and in institutions of higher education.

Applying to Bugscope has been purposely made easy. Classrooms propose their own projects, along with a preferred date and time. All legitimate proposals are accepted. Classrooms can either mail their specimens or use those provided by Bugscope. Teachers can schedule an interactive practice session to become familiar with using the microscope remotely. Teachers can also review archives of previous sessions. A typical session may range in length from 30 to 120 minutes.

Teachers and their students are responsible for planning their own scientific investigations to make the most efficient use of the time that they have been allocated on the microscope. Like professional scientists in different fields, they have an infrastructure of resident experts, such as the microscopist or an entomologist, to assist them in their investigations.

A standard classroom light microscope allows a magnification of around 1000×. Bugscope, which permits high-resolution imaging at over 20,000×, presents a unique opportunity for classrooms to collect data while discovering and understanding insects. For example, second-grade students from Milwaukee, Wisconsin, after seeing their specimens at a magnification of up to 10,000×, had the chance to "broaden their exposure to deeper understanding of the structures insects possess and perhaps widen their basic understanding of the microscopic world" [p. 31 in (*6*)] (see the second figure).



Microscopy suite. The microscope is used by remote classrooms, as well as by Beckman research scientists.

An illustration of live chat interaction. Students take control not only of the microscope but also of posing questions to experts (2010-106 session). Responses are intentionally made accessible for students in different grades.

PHOTO CREDIT (TOP AND BOTTOM): UMESH THAKKAR

[1]Department of Teacher Education, College of Education and Allied Studies, California State University, East Bay, Hayward, CA 94542, USA. [2]Coordinated Science Laboratory, University of Illinois, Urbana, IL 61801, USA. [3]Office of Public Health, Veterans Health Administration, U.S. Department of Veterans Affairs, Washington, DC 20420, USA.

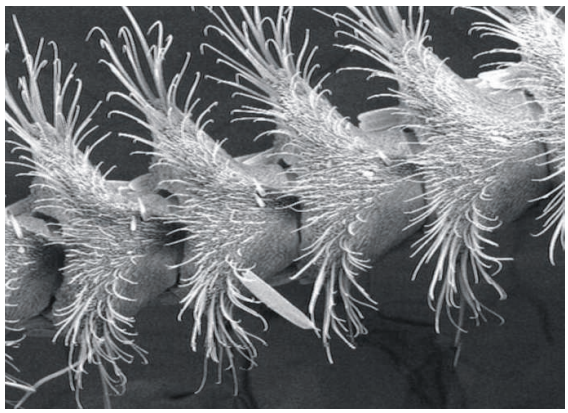
*SPORE, *Science* Prize for Online Resources in Education; www.sciencemag.org/site/special/spore/.

†Authors for correspondence. E-mail: michele.korb@csueastbay.edu (M.A.K.); uthakkar@illinois.edu (U.T.)

Downloaded from www.sciencemag.org on July 28, 2011

Published by AAAS

A recent report outlines a goal to prepare 100,000 trained middle and high school science, technology, engineering, and mathematics teachers by 2020 (*7*). Rather than just delivering content, undergraduate educators are being urged to address ways in which students and future teachers are prepared to gather and interpret scientific evidence and participate in scientific discourse (*8*). Projects like Bugscope in teacher education programs have the potential to increase relevant and meaningful uses of technology in K–12 classrooms. For example, in a typical Bugscope session in a science methods class, preservice teachers bring their own specimens to class (duplicate specimens are mailed to Beckman), make a drawing of the insect, and write questions they have regarding it. Next, their instructor models the use of Bugscope and trains the preservice teachers to use the microscope themselves. Throughout training, the class communicates via chat with the Bugscope experts. These preservice teachers also compare their drawings to images they acquired via Bugscope. Finally, preservice teachers are asked to design ways in which this experience can be implemented in a K–12 classroom, to explain how it contributes to inquiry and content knowledge, and to discuss how to manage their own sessions.



Questions asked while acquiring an image. An image acquired during a fifth-grade classroom session facilitated by a graduate of the preservice teacher education program at Marquette University (2009-154 session). Students viewed a loose wing scale on the antenna of a yellow butterfly (358×). While the image was present on the screen, questions were posed to experts, such as, "What is the purpose of an antenna?" and "What does it take to be you guys? What type of classes do you take?"

Thirty Bugscope sessions in teacher education programs at Marquette University and California State University, East Bay, over the past 10 years (involving 870 students) have modeled strategies for use of technology to foster inquiry in a dynamic, real-time community of learners by contextualizing science content. The preservice teachers can ask and receive immediate answers to their questions (such as "Why are there 'hairs' on the insect?") immediately from experts. These sessions allow future teachers to experience planning the integration of technology as they engage in it firsthand. From these experiences, preservice teachers have devised ways to use Bugscope to identify misconceptions and to infuse science across the curriculum. For example, its use in teacher education programs demonstrates that benefits include encouraging student engagement in scientific behaviors and dialogues, exposing students to scientists and scientific careers, creating ownership among students in learning about insects, building a relevant context within which to learn and apply scientific language, modeling data collection using an advanced scientific instrument, and providing applications that meet national and state science education content standards.

Seven recent graduates from two teacher education programs have implemented Bugscope sessions into their curricula. Some used the Bugscope session to stimulate student inquiry skills, while others had students create accurate insect sculptures based on the images they collected. In some classrooms, they guided students to use content and information from the chat transcripts to incorporate proper terminology into their writing. These sessions occurred during the regular school year and in summer school classes aimed at urban youth (see the third figure).

Reflecting on their preservice teacher education courses, two educators summarized what is exciting, engaging, and unique about Bugscope:

> "My students, who experience poverty, violence, and challenging living environments, had the opportunity to control a $600,000 environmental scanning electron microscope. They chatted directly with scientists …. Most students learn the functions of insects by looking at pictures or drawings in a textbook. However, my fifth graders observed their own once-living specimens."

> "The power of Bugscope to transform science education cannot be underestimated. At a time when science has become merely an addendum to Math and Language-Arts curriculum in most public schools, Bugscope provides a powerful and instantaneous revitalization to a dying art … that of personally engaging and connecting students to the wonders of scientific inquiry and exploration."

In successful online learning environments, students learn from engagement in scientific processes by challenging what they know in order to add to their understanding of how the world works (*9*). Bugscope is a sustainable and scalable model for classrooms nationwide to conduct their own scientific investigations.

About the Authors

M. A. Korb completed her Ph.D. in science education at Marquette University, where she incorporated Bugscope into her preservice teacher courses. She is an assistant professor in the Department of Teacher Education at the California State University, East Bay, and is a coprincipal investigator on an NSF Math and Science Partnership grant award 0962804. **U. Thakkar** has directed education and outreach of Bugscope since the beginning. He is a senior research scientist in the Coordinated Science Laboratory at the University of Illinois and is serving as a AAAS Science and Technology Policy Fellow in Washington, D.C.

PHOTO CREDIT: IMAGE ACQUIRED BY STUDENTS (2009-154 SESSION)

References and Notes

1. The session members' page from the Winchester Thurston School includes the teacher proposal (http://bugscope.beckman.illinois.edu/members/2010-106).
2. NSF Cyberinfrastructure Council, *Cyberinfrastructure Vision for 21st Century Discovery* (NSF, Arlington, VA, 2007); www.nsf.gov/pubs/2007/nsf0728/index.jsp.
3. NSF Task Force on Cyberlearning, *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge* (NSF, Arlington, VA, 2008); www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf.
4. U. Thakkar *et al.*, Formative evaluation of Bugscope, paper presented at the American Educational Research Association Annual Meeting, New Orleans, LA, 24 to 28 April 2000; http://itg.beckman.illinois.edu/archives/technical_reports/00-008/00-008.pdf.
5. S. Robinson, C. Conway, C. Wallace, A. M. Ray, U. Thakkar, *Microsc. Today* **19**(02), 46 (2011).
6. K. Hadley, M. A. Korb, *Sci. Child.* **45**(1), 29 (2007).
7. President's Council of Advisors on Science and Technology, *Prepare and Inspire: K–12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future* (Executive Office of the President, Washington, DC, 2010); www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf.
8. B. Alberts, *Science* **319**, 1589 (2008).
9. C. E. Wieman, W. K. Adams, K. K. Perkins, *Science* **322**, 682 (2008).
10. The authors acknowledge all Bugscope team members, especially S. Robinson and C. Conway. Bugscope started with an NSF grant award 0081117 to C. Potter and B. Carragher to direct its development.

10.1126/science.1196981

Downloaded from www.sciencemag.org on July 28, 2011

Published by AAAS