Bees and Pollination: A "Scientist" Experience for Rural Youth in Oregon

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"Look! There's a *Bombus* and an *Agapostemon*!" screamed 6th grade students as a large black-and-yellow bee and a smaller shiny green native bee alighted on flowers on the school grounds. These were students in Seven Oak Middle School in Lebanon, a rural community in western Oregon that participated in Oregon State University's Discovering Partners in Nature program.

Children have an innate curiosity about insects. They grab them and hold them, and they examine them fearlessly, making new discoveries with every insect that they encounter. Sadly, as they grow older, the "entomologist" in children is lost because of perceptions that bugs are "yucky," scary, and not "cool," or because of lack of encouragement from parents and teachers who may themselves be intimidated by insects.

The innate curiosity about insects can be fostered if children are offered rewarding entomological experiences—after all, experience is the greatest teacher. One strategy for sustaining entomological curiosity in children is to get them involved in certain aspects of university research. Not only can such partnerships enhance children's knowledge and appreciation for insects, they can change stereotypic perceptions about entomologists and scientists in general, and motivate youth to consider careers in entomology or other science-related disciplines. Here we describe an innovative program at Oregon State University (OSU) through which university researchers engaged students in four rural communities in an ongoing research project and provided them with a typical scientist's experience.

The program, funded by a grant from Toshiba America Foundation, creatively used a "pollination unit" to introduce middle school students to activities that scientists typically engage in: asking questions, conducting experiments, recording data, and drawing conclusions. Simultaneously, the students learned about their local flora and fauna, how plants and insects interact for mutual benefit, and how technology contributes to scientific research. A unique part of the program was a conference held on campus at which students presented their results to peers, academics, stakeholders, a representative of the funding agency, and community members.

The Discovering Partners in Nature program was the serendipitous result of a field trial that evaluated pheromone traps for their potential in attracting adult cereal leaf beetle, a recently introduced pest in oats, wheat, and barley in Oregon. Pherocon® provided black, green, white, painted blue and yellow, and fluorescent yellow and blue traps (Fig. 1) for evaluation in the study.

The fluorescent blue traps did not attract cereal leaf beetle adults, but they captured a diversity of native bees, especially bumble bees. Other than hymenopterans, few other taxa were captured (Stephen and Rao 2005). We decided to use the blue traps for a study on bee diversity in the Willamette Valley in Oregon and to determine whether we could detect the presence of *Bombus occidentalis* Greene. This species was once the most common bumble bee found in western America (Thorp and Shepherd 2005), but it is now perceived to be extinct. We also decided to integrate an existing OSU–K12 partnership (Rao et al. 2003) into our efforts and involve rural youth in our research through the Discovering Partners in Nature program.

Program Plan

The project was implemented in four schools within a 30-mile radius of OSU's Corvallis campus: Falls City Elementary School, Seven Oak Middle School in Lebanon, Central Linn High School in Halsey, and Inavale School at the outskirts of Corvallis. The schools were located in rural communities, and although they were limited in resources, the schools were surrounded by landscapes that presented excellent opportunities for entomological explorations. At Inavale School, students in the after-school Bee Club participated in the program with assistance from a community member. Their research site was a private ranch in Monroe, a neighboring rural community.

OSU participants included entomologists, a botanist, the director of the scanning electron microscope facility, and an entomology graduate student who was supported by a National Science Foundation GK–12 grant.

Fig. 1. Semitransparent blue trap that attracts diverse species of native bees.

The NSF grant for enriching science education in rural schools in Oregon was used to place OSU graduates and undergraduates in K-12 classrooms and to develop and implement hands-on inquiry-based activities (Rao et al. 2003). With the funding from Toshiba America Foundation, we obtained resources for a new pollination unit, supported visits to the university campus, and provided students with the experience of attending a conference similar to professional society meetings.

Fig. 2. Students from Seven Oak Middle School collecting insects during visit to OSU campus.

Program Activities

Development and implementation of a pollination unit. The pollination unit was developed at OSU in collaboration with science teachers in participating schools. In early fall, middle school students determined the bee fauna on the school grounds. They set up the fluorescent blue traps at various locations and retrieved them after 48 hours. They separated the bees, mounted them, and identified them using an identification key developed at OSU (Stephen and Rao 2006). Simultaneously, they collected flowers from the school grounds and adjacent areas. These were then pressed and dried using standard plant presses provided by OSU and mounted (glued) on standard herbarium paper. A dichotomous key was developed at OSU to help students identify the plants they had collected. Students examined bees and flowers and later built models to learn about structures involved in pollen transfer and fertilization.

Classroom discussions on mutualism and pollination and their relevance to food production. Students participated in discussions on the value of bees and other pollinators in vegetable and flower gardens, and in agricultural systems surrounding their homes. They debated the benefits of bees in pollination versus the negative aspects associated with bee stings. Close encounters with bees helped them replace fear with curiosity and respect for bees. Their plant and bee collections from the school grounds stimulated discussions on the value (economic, cultural, etc.) of native and nonnative species, their effects on the local ecology, the reasons some plants are weeds and others are not, and the use of native plants for restoration projects and as ornamentals.

Bee pollination research by middle school students. After their initial exposure to bees, flowers, and pollination, the students were trained to conduct research. In the original plan, students were to be assisted in examining pollen on the bees and on flowers to discover for themselves which bees pollinate which flowers. However, as is typical of many scientific experiments, plans had to be modified when we discovered that most of the trapped bees lacked pollen on their bodies. This suggested that the traps were attracting bees on their outgoing visits to flowers: an exciting discovery for us, but one that required a change in our plans. The change, however, allowed us to train students to ask research questions. They worked in groups of 4 or 5 and selected a topic for research using knowledge of plants and bees acquired during the year. Topics chosen included:

- What time of day do bees come out the most?
- Do different bees come out in different seasons?
- Do flowers placed in the traps attract bees to traps?
- Which bee structures hold the most pollen?
- How much pollen can a bee collect at once?
- Do pollen from native and nonnative plants have structural similarities?

Students in each group designed and set up their experiments on the school grounds in the spring. They collected data, interpreted the results, and prepared oral and poster presentations based on their findings.

Campus visit. All of the participating students visited OSU and toured the scanning electron microscopy (SEM) facility. Students were shown the magnification capabilities of SEM technology while they viewed images of pollen grains and of hairs and other pollen-collecting structures on the legs and abdomens of bees they had collected and mounted earlier in the year. They received photographic images of their samples to use in their presentations. While on campus, the students toured the OSU Insect Collection and the Herbarium. After lunch at the Memorial Union, they were given insect nets to explore the entomological fauna on the university grounds (Fig. 2).

Discovering Partners in Nature Conference at OSU. A "Discovering Partners in Nature" conference was held at the OSU LaSells Stewart Conference Center in late spring. Participating students "registered" for the conference and were given a name tag and a folder with the agenda.

After a brief introduction, the keynote presentation was a collaborative talk by OSU's bee expert, W. P. Stephen, and students selected from each participating schools (Fig. 3). Teachers, community members, and a member of the Oregon Bee Keepers Association also made brief presentations. Between the talks, pollination-related questions were flashed across the screen to be answered by the audience. This was done to keep the

Fig. 3. Students making a presentation on their research during the Discovering Partners in Nature conference at OSU.

students engaged during the event, and to draw on the knowledge they had acquired during the year. During the poster session that followed, participating students stood by their posters and answered questions posed by their peers and by other conference attendees (Fig. 4).

Program evaluation. We assessed the program in two ways:

A "Before" and "After" Quiz was developed with questions related to bees, flowers, and pollination. Participating students took the quiz in the fall before the program began, and again in spring after the campus conference. We compared scores to determine the influence of the program on the students' understanding of the topics covered in the pollination unit.

After the conference, students submitted a reflection paper on their experiences.

Fig. 4. Student answering questions pertaining to his group's poster posed by John A. Anderson, Jr., President Toshiba America Foundation, who visited Corvallis for a day just to attend the Discovering Partners in Nature conference at OSU.

Program Outcomes

The program facilitated a shift from traditional memorization of scientific facts to inquiry-based learning in which students were trained to seek answers to their own questions, as endorsed by the National Research Council standards (2000). Insects, and bees in particular, have been used in diverse programs for integrating inquiry-based activities in K-12 classrooms (Ellis et al. 1999, Golick and Ellis 2003, Rao et al. 2003). However, our program documented their use in providing an all-encompassing scientist experience, including

- asking questions,
- setting up an experiment,
- collecting and interpreting data,
- participating in discussions on the relevance of their research to society, and finally,
- presenting their results to peers at a scientific conference.

The program involved 127 students and 6 teachers in four rural schools. More than 150 people attended the year-end conference. An unexpected and welcome visitor was the President of Toshiba America Foundation, **John A. Anderson Jr.,** who traveled from New York to Corvallis specifically for the conference.

Impacts on K-12 Students

K-12 students benefited at multiple levels by the pollination unit, interactions with university researchers, visits to the large university, and the scientific experience that they were provided. Besides the opportunities for hands-on inquiry-based science, the program enriched their scientific vocabulary. A comparison of "Before" and "After" scores on the pollination quiz indicated a doubling of the score (Fig. 5), and 10% of the students received perfect scores on the "After" test.

The teachers appreciated that their students were able to learn proper techniques for identifying and preserving scientific specimens that they could not have provided. Other new learning experiences included pinning bees; developing the ability to distinguish between wasps, native bees, and the European honey bee; and using a dichotomous key to identify bees in 17 genera. Students learned to use a plant press to preserve plants and to identify 21 plant species, including nonnative species such as tansy ragwort and St. John's wort. They also learned an important part of any scientific study—the need to document their work with voucher specimens.

During their visit to the OSU Insect Collection and the Herbarium, students learned to use procedures for long-term preservation of plants and insects. One student, after seeing specimens in the OSU Herbarium during the campus visit, proudly exclaimed "We did that! [in the classroom]."

Through the program, students got to use technology and equipment that would not have otherwise been available to them. Integration of advanced scientific technology with their classroom activities was a unique experience for them. One student commented that he did not know that microscopes had integrated with computers. SEM images highlighted to them the great diversity and complexity in pollen grains, hairiness of bee legs, and phoresy by mites on bees.

This program allowed rural youth to get acquainted with OSU researchers, gave them opportunities to ask questions about college, and enhanced their comfort level during their on-campus experiences. The students' reflections documented the tremendous value of the scientist experience in changing their perceptions about scientists, and in normalizing the idea of attending college for students, who because of their backgrounds were less inclined to pursue higher education.

Student comments include:

"*I have a better idea of what I wish to study in the future*,"
"*Doing the project makes me anxious to go to college,"*
"Now I want to be a scientist,"
or more specifically, "*I wish to work as a bee scientist*."

The OSU-K-12 conference helped alleviate the isolation felt by rural students. They benefited by the new experience of interacting with peers from other rural schools, "*talking to different people that I did not know before*," and listening to "*what others students had to say about bees*." The experience of preparing a poster for the conference was "*awesome*," and making the presentation in front of 150 people gave the students "*confidence in front of people*." One student was "*surprised at what some of the adults didn't know; some of what they did not know, we did*." Meeting with the President of Toshiba America Foundation overwhelmed the students—"*He cared enough to come all the way!*" At the end of the program, one student wished that she could *"do it all over again."*

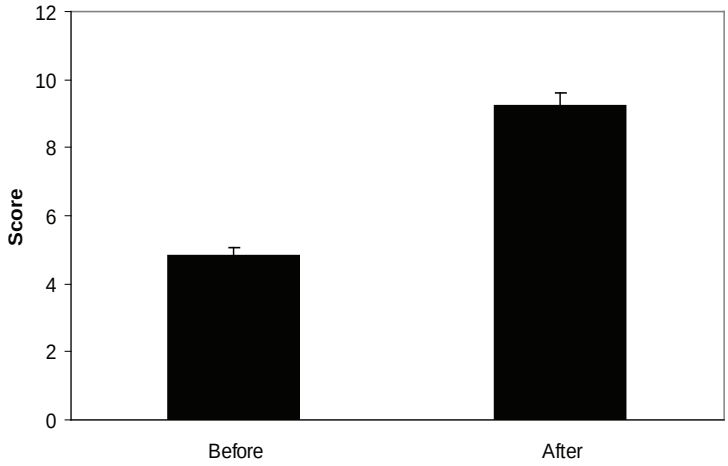

Fig. 5. Mean "Before" and "After" test scores on pollination quiz administered to students in 3 participating rural schools.

Impacts on the University

The program was multidisciplinary and included faculty from the College of Agriculture, and the College of Science. Visits to the university by K-12 students and OSU involvement in the local communities enhanced the image of the university. OSU researchers served as role models for K-12 students, motivating them to consider science.

The OSU graduate student who participated in the program benefited professionally in being able to build relationships with OSU faculty and staff who would otherwise not be involved in her program of study. Her communication and presentation skills were enhanced, and she now exhibits improved organizational and time management skills. She is motivated to integrate outreach in her research program and to connect her research to the community.

Bees collected by participating students added to our bee diversity study. Overall, specimens belonging to 35 native species in 17 genera in 5 families were added to the OSU Insect Collection. Although *B. occidentalis* was not recovered, relatively rare species in parasitic genera *Nomada* and *Sphecodes* were collected. The genus with the highest representation was *Bombus* (seven species) followed by *Melissodes* (five species); only two species of the green halictids (*Agapostemon*) were captured, but their numbers were overwhelming.

A Model System

This program can serve as a model system for integrating K-12 science education with university research in diverse disciplines besides entomology. Including university students in such programs is valuable because they serve as role models and motivate youth to consider a career in science. The university students also value the K-12 outreach experiences for enhancing their communication skills and making them more competitive in the job market, and their interactions with K-12 students leave a lasting impression on them (Rao et al. 2003, 2007). Integrating university research with the outreach experience enables graduate students to better understand their own research. We believe that funding for such outreach should be included on research grants so that the broader impacts of the research become available to the lay audience. Alternative creative options include developing service-learning courses on science education and outreach (Rao et al. 2007), during which on-campus students can develop and implement activities for K-12 classrooms that integrate university research. Partnerships between university researchers and K-12 schools are valuable for changing stereotypic perceptions about scientists and exposing them early in life to opportunities at institutions of higher education for enriched and exciting experiences in science.

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