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Bumble Boosters: Doing Science as a Community of Learners

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Education Connection

Bumble Boosters: Doing Science as a Community of Learners

Douglas A. Golick and Marion D. Ellis

Bumble bees are an excellent organism for engaging high school students in research. They are a recognizable insect and an important pollinator, and much remains to be discovered about the biology of many species. Bumble Boosters was a teaching and research project funded by the Nebraska Lottery's Educational Innovation Fund. The project began in June 1999 and ended in June 2002.

Bumble Boosters created a community of students networking through the Internet to conduct authentic research on Nebraska bumble bee species. Throughout the state, 40 high schools participated in the project, which included teaching and research objectives. Teaching objectives were to raise student and public awareness of the environmental importance of pollinating insects, enhance students' understanding of the process of conducting scientific investigation, increase students' knowledge of insect biology and pollination ecology, engage students' abilities in networking with other students and leaders to solve a shared problem, and develop students' abilities to use Web pages to learn and to share information.

The research objectives of the project were to better define the distribution and diversity of bumble bee species in Nebraska, identify the floral species that are preferred by Nebraska bumble bee species, and investigate artificial domiciles for improving the nesting success of Nebraska bumble bee species.

Why Bumble Bees?

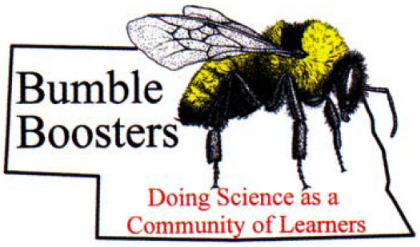
Why would students want to study bumble bees? With the decline of wild honey bee populations due to the introduction of the varroa mite, many people have an interest in encouraging native pollinators (Buchmann and Nabhan 1996). Bumble bees are important, excellent native pollinators. They pollinate a broad spectrum of floral resources including much of our native flora. They also are economically valuable because of their exclusive use as greenhouse pollinators for tomatoes and a variety of vine crops (Matheson 1996).

Project Overview

Bumble Boosters capitalized on an existing collaboration between the University of Nebraska Department of Entomology, Lincoln Public School's Science Focus High School, and the Lincoln's Folsom Children's Zoo. The partners have collaborated since 1996 to offer an outreach event called "Bug Bash" (Ellis et al. 1999). As a natural outgrowth of this collaboration, the partners worked to submit a grant proposal to the Nebraska Lottery's Education Innovation Fund. In 1999, the grant proposal was funded for a three-year period.

The first year of the project was a pilot program of 10 schools. The high school science teachers evaluated the teaching resource materials, the project Web site, and the protocol that the partners had developed. Participants were asked to provide feedback and suggestions for project improvement. An outside evaluator provided a formative evaluation. Feedback from the pilot project cooperators and the evaluation provided guidance in the planning and implementation in years two and three.

In the second and third years, 30 additional schools were recruited from all regions of the state. The third year was dedicated to collecting and evaluating data. The project concluded with a summative evaluation by an independent consultant.



Bumble Boosters project logo.

Distribution and Abundance of Nebraska Bumble Bees

One of the main goals of Bumble Boosters was to determine the distribution and abundance of Nebraska bumble bee species. Prior to this project, two surveys of Nebraska bumble bees had been done. In the early 1900s, M. H. Swenk focused on the western portion of the state (Swenk 1907). His results were reported as part of a general survey of the state's flora and fauna. Swenk's collection sites were scattered in distribution, and many areas were not included in his survey. LaBerge and Webb (1962) conducted a second and more extensive survey, which covered the eastern and extreme western portions of the state but neglected the central region. The data from this survey came largely from the authors' personal collections and the state museum collection. In the 1962 survey, 20 bumble bee species were found in Nebraska.

The most important factors in bumble bee abundance are availability of nesting habitat and forage plants (Mussen 1999). Since the 1962 survey, the ecological landscape of the state has changed significantly, including loss of nesting habitat and forage plants to urbanization, the introduction of nonnative plant species, the conversion of alfalfa meadows to row crops, and rises and declines in managed and feral honey bee populations (NASS 2003).

Bumble Boosters' Collections

Nebraska is a large state with many ecosystems. To get a complete picture of distribution of bumble bee species, the 40 high schools were located throughout the state to collect bumble bees in the area around their schools. Students and their teachers collected bumble bees in the spring, summer, and fall each year. In the summer and fall, participants collected bumble bees to create a reference collection. Participants used aerial nets and glass collection jars to capture bumble bees.

Specimens collected for reference collections were killed with ethyl acetate. Collection data for each specimen was included on the specimen labels and recorded on data sheets. The specimen records included the location, collector, floral species, bee gender, and species. Schools submitted their reference collections to project coordinators at the University of Nebraska, Department of Entomology, where specimen identification and collection information were verified by experts in bumble bee identification. Collection data were recorded in a database and posted on the project Web site. Reference collections were sent back to the schools with comments about any misidentified specimens. In the spring, participants were encouraged to collect, but not kill, bumble bees because most spring-collected bumble bees are queens establishing nests for the year (Alford 1975). Participants collected bumble bees in glass jars and chilled them in a cooler that contained an ice block. When chilled for 20 minutes, bumble bees become inactive and can be removed from the jar for observation. Once data were recorded for the specimens, including tentative identification, bumble bees were released near the capture site.

Data from spring collections were not included in the research results because species identification could not be verified by project coordinators. However, students gained valuable experience in collecting and identifying bumble bees. Although spring collection would probably have had a minimal impact on populations, we chose a catch-and-release strategy to teach a conservation ethic and an important lesson about the bumble bee's life cycle.

Many students became experts in identifying bumble bees

Artificial Domiciles

In the spring, solitary bumble bee queens seek out suitable nesting sites. They frequently choose abandoned rodent dens, either on the surface or in underground cavities (Sladen 1989). Bumble bees occasionally will choose other sites to establish a nest, ranging from neglected compost heaps to abandoned couches. The goal of making and distributing artificial domiciles is to provide nest sites for queens where nesting sites are limited. During the past century, several researchers tried, with limited success, to create a domicile that was readily accepted. The highest acceptance rates for North American bumble bee species were reported by Frison (1926) at 42%, Fye and Medler (1954) at 34%, and Hobbs (1967) at 45%.

Most other studies reported little or no success. Designing an attractive domicile provided students with a challenging opportunity to contribute to our understanding of nest selection behavior.

During the pilot year of the project, the 10 participating schools were given eight preconstructed artificial domiciles, which had been designed based on research articles that reported some success. Participants placed the preconstructed domiciles around their schools. Predictably, the success of preconstructed domiciles followed previous research results, with poor acceptance rates.

To improve acceptance rates and increase the science inquiry element of the project, we decided that during the second and third years participants would be asked to create their own artificial domicile designs. We provided data about what is known about bumble bee nest selection and challenged students to develop their own designs. All designs were replicated and distributed randomly. During this phase of the project, schools created and placed more than 400 artificial domiciles. Designs ranged from simple habitat modification, such as a hole in the ground with insulating material, to a buried

Teacher training workshops were conducted each year of the project.

Outside cover of *Bumble Boosters: A Guide to Identifying Nebraska Bumble bee Species.*

lawn ornament filled with cotton batting. Participants were guided to apply the scientific method to this aspect of the project. Teachers helped students identify the problem, form a hypothesis, and design an experiment to test the hypothesis that included, replication, randomization, and analysis of the results.

Teacher Training

During the spring of each project year, we held training workshops at locations in the eastern, central, and western portions of the state. Teachers were given an overview of bumble bee biology and were guided in how to implement the project. All participants received a resource kit. To boost teacher confidence in identifying bumble bee species, a considerable portion of training was dedicated to identification. Training sessions also gave participants an opportunity to ask project coordinators questions, offer suggestions, and to form links with other schools.

Resource Kits

During the training sessions, participating schools received a research kit that included five reference books, 20 identification guides, and supplies for collecting, pinning, and shipping specimens. One of the important items of the kit was *Bumble Boosters: A Guide to Identifying Nebraska Bumble Bee Species*, which we developed for this project (Golick and Ellis 2000). This compact, durable guide book is based on the distinctive hair color patterns of bumble bees. We created a new visual key rather than using LaBerge and Webb's dichotomous key (1962), which often requires a high-quality dissecting scope and an extensive knowledge of morphology. The identification guide grouped species with similar color patterns that could then be distinguished from one another by morphological characteristics observable with the aid of a 10× hand lens. The effectiveness of the guide was apparent when one school submitted 778 specimens, of which 95% were correctly identified.

Beginning in the second year, lesson plans were included in the teaching kits. We created eight lesson plans for implementing Bumble Boosters and extending learning:

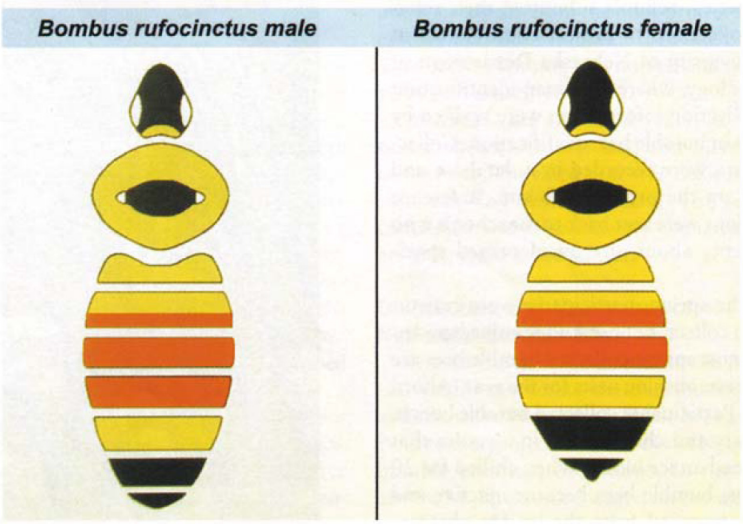
- The Value of Pollination
- The Classification of Living Things
- The Process of Scientific Inquiry, Spring Collecting and Identifying of Bumble Bees
- Summer Collecting and Identifying of Bumble Bees
- Placing Artificial Nesting Domiciles to Attract Bumble Bees
- Can Bees Tell Time?
- Artificial Habitats for Tube-Nesting Bees.

By including the lesson plans, questions about how to implement the project in the classroom decreased, and the steps of the project were better defined.

Web-based Resources

An integral part of Bumble Boosters was the use of the World Wide Web to facilitate networking and communication between participants. The hub of Bumble Booster's community was the Web site http://bumbleboosters.unl.edu, which provided resources on bumble bee biology, project lesson plans, collection records, tools for bumble bee identification, and answers to frequently asked questions.

Of special interest on the site was the *Bumble Bee Identifier*, an interactive key used in identifying bumble bees to species based on the *Bumble Boosters* guide (Golick and Ellis 2000). Users change the color of body segments of an online diagram of a bumble bee and match it to the hair color pattern of the specimen they want to identify. Once users are satisfied that the diagram matches their specimen, they click the submit button. If they have correctly matched their specimen to a Nebraska species, the *Bumble Bee Identifier* gives them the species name, images of different views of that species, and a state distribution map. If they have not matched a species, they are taken to diagrams that display all Nebraska species so they can look for a match to their specimen. Another important online communication tool for participating teachers and project coordinators was the project discussion list. The dis-



The guide uses hair color patterns of bumble bees for species identification.

With a little training, students quickly learned how to capture bumble bees.

cussion list facilitated communication and collaboration between participants and allowed project coordinators to answer teachers' questions. More than 200 posts were made by project participants during the pilot year of the project.

School Visits

Visits to schools by project coordinators were an important component of the program that increased school participation and student success. During visits, coordinators worked with students on collecting techniques and identifying their specimens. An important benefit of school visits was boosting the students' and teachers' confidence in collecting stinging insects. Initially, many participating teachers had concerns about students being stung while collecting bumble bees. During training sessions, project coordinators discussed bumble bee biology and the fact that bumble bees do not exhibit a defensive response away from the nest unless touched. For some teachers, simply giving them this information was not enough. School visits gave teachers and students the opportunity to be coached by experts on the techniques of collecting bumble bees with the use of aerial nets and glass jars. With a little training, students quickly mastered collecting techniques and were comfortable handling bumble bees. As testament to the success of the training, there were no reports of students being stung by bumble bees throughout the entire project period.

Results and Lessons Learned

Bumble Boosters participants collected 3,219 bumble bees, and 107 new county records were established for bumble bee species in Nebraska. Nineteen of the 20 previously reported bumble bee species in Nebraska were collected, along with a single specimen of a species not previously reported in the state. However, project leaders were not successful in collecting the species again when they visited the site during the same month of the following year. Bumble bee populations can

Some schools went to great lengths to create artificial domiciles. Students from biology and industrial art classes at Clearwater High School worked together to construct these domiciles.

Students placed artificial domiciles in the field before queen emergence in the spring.

vary greatly from year to year (Free and Butler 1959). The site will continue to be monitored, and the species will be added to the list of Nebraska species if it is collected again. Bumble bees were collected on -50 plant species. Floral collection data are being incorporated into an extension publication on planting a pollinator garden. None of the artificial domiciles were used by nesting queen bumble bees. Students were disappointed, but they learned that scientific discovery requires perseverance. Despite disappointment, many teachers cited the artificial domicile lesson as one of the most valuable learning experiences. Several teachers noted that the possibility of failure made the project challenging, and it taught students that scientists make discoveries by trial and error and that experiments do not always have predictable outcomes.

Project coordinators also learned many things from Bumble Boosters. We gained a profound respect and appreciation for high school science teachers, and we celebrated when three collaborating teachers were recognized by the Nebraska Chapter of Sigma Xi as the Outstanding High School Science Teacher in 1999, 2001, and 2002, respectively. Participation in teacher training workshops and follow-up school visits were critical to success. Schools that received handson training from experts collected more specimens and were more successful in implementing all aspects of the project.

Bumble Boosters can serve as a model for similar projects that focus on a collaborativepartnership between postsecondary and high schools in conducting real research. We propose that it is an excellent strategy for teaching high school students science process and content. The National Science Standards (National Research Council 1996) place a high value on scientific inquiry in the classroom.

Last, but not least, the participating students made a valuable contribution to our knowledge of the distribution and abundance of bumble bees in Nebraska and the floral preferences of each species. They also brought a heightened recognition of the value of pollinating insects to their communities. Students experienced the fun and excitement of scientific inquiry. One teacher commented that former students who graduated the previous year continued to discuss new ideas about artificial domiciles.

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