INSECTS AS TEACHING TOOLS IN PRIMARY AND SECONDARY EDUCATION

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ABSTRACT
Insects offer a vast array of teaching opportunities for precollege students. Here we address the basics teachers need in order to use insects successfully in their curricula. We identify exemplary resources in the printed North American literature and point out potentially productive places for teachers and students to search for ideas and materials. We review the roles of entomology in the educational framework, highlight favorite classroom arthropods and less well-known examples, and guide readers to entomological resources. Tips to help teachers identify, rear, and maintain classroom insects and find equipment and supplies are included. The review concludes with a plea for greater classroom and curricular involvement by those in the entomological profession.

INTRODUCTION
It’s a natural match—students that are curious about the world around them and insects that offer a nearly inexhaustible well of stimulating material with which teachers can feed that curiosity. A staggering array of potential resources features insects or other arthropods as teaching tools. In this review, we provide a guide rather than a catalog or encyclopedia. We present those that we feel have a strong potential to provide a positive learning experience, and we identify potentially productive places for teachers and their students to search for ideas and materials.
We concentrate on North American printed literature. Videos, films, software, compact disks, and the like are a world of their own, well deserving separate consideration. Given the rapidly changing world of computer-based communication, we have only hinted at resources available through the Internet, World Wide Web, and other online services, though we expect that much of what is mentioned here will eventually be available through electronic channels (150, 159).

Because this review is for use both by entomologists wishing to teach school children and by teachers wishing to incorporate entomology into their classrooms, we organize it around some very basic questions:

1. Why should we use insects in the classroom?
2. What can we teach and learn with them?
3. Which insects should we use?
4. Where should we do this?
5. How do we get started?

THE CASE FOR INSECTS IN THE PRECOLLEGE CLASSROOM

Why should a teacher use insects in the primary or secondary school (i.e. K–12) classroom? The question is hardly new. Twenty years ago, Creager (45) replied by noting insects’ sheer numbers, diversity, adaptability, and evolutionary success, and Fischang (74) urged that “an understanding of insects is in a sense a prerequisite to a broader understanding of life.” Similar arguments still apply (211). One might add the aesthetic value of insects, as manifested in the beauty of their many forms, and the impact of insects—both beneficial and detrimental (2)—on human affairs.

Why aren’t insects already in every classroom? It’s a matter of attitude, training, and background (95). Some arthropods generally evoke good will; others are generally regarded as repulsive. Popular literature and films feed our biases. On the one hand we have the fictionalized charisma and charm of spider Charlotte and her web (259), on the other, “killer bees” (78, 129, 201). In the natural world, the arthropods we most often notice are those associated with discomfort or danger (114)—ants, mosquitoes, ticks, scorpions, cockroaches, and wasps. Furthermore, there is a lot of information, a tremendous number of kinds of insects [more than all other animal groups combined (261)], and much of what could be known about them is still undiscovered. For a scientist,
this is captivating. For the average primary or secondary school teacher, it is
discomfiting and intimidating.

Teacher education programs often inadequately prepare teachers for the real
world of the classroom. A survey of teachers of seventh grade (i.e. 12- to 13-
year-olds) life science in Georgia (TR Koballa Jr, unpublished data) revealed
that most received no more than one to two weeks of instruction on arthropods,
mostly as a part of a general survey of the animal kingdom. Fewer than 5%
had undertaken any formal university-level course work in entomology as a
separate discipline.

However, an abundance of new instructional materials using insects and other
arthropods has been and is continuing to be developed and marketed (178). The
trend is driven by several factors. The purest is an increased appreciation of
the significance of arthropods, given their sheer numbers and diversity (261).
Another is the increase in animal welfare concerns and concomitant increases
in regulations affecting research and teaching (10, 155). Many processes that
occur in all living organisms can be observed firsthand in insects with fewer
restrictions than have been placed on vertebrate animals. A third factor is pure
practicality. With relatively short life cycles and dramatic physical changes
during development, insects lend themselves well to laboratory study. They
make excellent teaching models, are easy to maintain, easy to handle, and
widely available. Finally, as Flannery (79) points out, in these days of tight
budgets, insects also make fiscally attractive laboratory subjects.

ENTOMOLOGY IN THE EDUCATIONAL FRAMEWORK

Most children are concrete learners (30, 111), able to think hypothetically only
when given concrete examples. Formal thinking often does not develop until
somewhere between the age of 14 and adulthood (30, 111, 122). Thus, scientific
theories and concepts can seem highly abstract and abstruse for many students,
even in high school and college. It makes good educational sense that the more
hands-on opportunities and real-life examples one can provide in the science
classroom, the better. In this, insects excel.

Basic Life Science Concepts

Many excellent compilations provide an extensive variety of entomology-
centered themes for any age group (e.g. 16a, 38, 48a, 49, 52, 94, 105, 112,
117, 118, 145, 250). Some center on insect structure and function, others on
behavior and ecology. Many also include suggestions for further study, such
as connections to music, art, and literature, or investigations suitable for more
extended individual student research projects. For example, the Biological Sci-
ences Curriculum Study (BSCS) minicourse investigates odor communication
in ants and sound communication in crickets in the broader context of animal communication (17). Similarly, an insect olfaction activity that observes fruit flies in a homemade wind tunnel (235) is adaptable to the study of other orientation responses to airborne odors. A demonstration of oxygen consumption in relation to temperature uses inexpensive, easily constructed apparatus appropriate to the secondary-level student (132).

Medical entomology has been relatively unexplored in American precollege education. However, because insects and other arthropods play such a significant role in disease transmission (2, 7, 183, 232), all of the major secondary school life science curricula give some textual mention to such diseases and public health issues as yellow fever, malaria, plague, body lice, bed bugs, bee stings, scabies, Rocky Mountain spotted fever, Lyme disease, encephalitis, and African sleeping sickness.

The interface between insects and public health offers many opportunities to move beyond library investigations of disease cycles and mechanics. Some curricular materials have incorporated a “case study” approach to arthropod-vectored diseases (7). For mosquito-borne diseases, Spray (232) is excellent, particularly for pre–high-school levels. For the early primary grades, an exemplary activities series (38) features 14 kinds of arthropods in 20 lessons that explicitly connect insects to human health concepts. A variety of engaging trade books offer opportunities to build upon this classroom study (93, 120, 124, 183).

Many people who admit to a love of other crustaceans such as shrimp, lobster, crayfish, and crabs would never willingly taste an insect, yet in many countries insects provide a significant protein source and certain species are considered delicacies. Teachers seeking novel ways to introduce nutritional concepts may find books and articles on eating insects to be food for thought (18, 21, 107, 180, 240, 241).

Personal health and environmental studies are intimately interrelated. Analysis of cockroach catches from commercial roach traps deployed in and around the school building (44) has been used to teach the concept of habitat. Similar studies focus on house and garden pests (257).

The environmental education movement has generated a vast number of resources for teachers and these often feature insects (e.g. 46, 217). However, this movement is not as new as might be supposed. Indeed, the classic 1911 manual by Anna Botsford Comstock (41) is still very useful for such guided insect study. Over the past decade, a popular local project has been to establish a butterfly garden. A number of resources are available to help teachers and students plan for the most effective nectar and caterpillar plants (96, 100, 197, 222, 224, 239, 243). Wild solitary bees and wasps are also attracted to many of
the same plants, and suitable nesting habitat can be provided that will increase
their numbers (8, 27, 72). A natural extension is to use these gardens for studies
of pollen and nectar foraging (48a, 98).

Many basic concepts can be taught through insect field studies. Goldenrod
galls are conspicuous components of old fields in eastern North America, and
some excellent field ecology studies have been outlined (76, 181, 190, 208). A
few feature scavengers, decomposers, or predators (108, 162, 170a). Termites,
easily obtained and maintained, are the focus of a good primary classroom
activity (94). For secondary students, a long-term field census uses a grid of
toilet paper rolls to sample for natural termite invasion (185). An activity with
carrion beetles and mouse carcasses in an ant farm apparatus deals with mating
systems and social conflict (245).

Science Skills and Attributes

Once, the primary goal of science education was simply to instill a body of basic
information within a student’s mind (173). However, with a rapid expansion
in both this body of knowledge and data on how children learn (33, 130),
curricular reform movements (6, 66, 247) have emphasized teaching the skills
and attributes students need to actively attain scientific information on their
own throughout their lives. The overwhelming consensus of science educators
(6, 36, 66) is that exploratory activities with an element of inquiry succeed best
in capturing interest, stimulating thinking, promoting content learning, and
developing scientific attributes (such as curiosity and inferential thinking) that
a real scientist uses. In general, inquiry teaching allows and promotes student
involvement in designing experiments and communicating experimental results
(195, 206, 215, 216).

Popular with elementary school teachers, “guided” inquiry units typically
include well-defined activities for familiar arthropods such as pillbugs (28),
 butterflies (34, 63, 176), mealworms (3, 256), ladybugs (65), honeybees (64), or
mosquitoes (68, 232). Creepy Crawlies and the Scientific Method (118) outlines
over 100 such activities. On the middle school or junior high level, popular
guided inquiry materials (7, 11, 104, 207) employ a Science, Technology, and
Society (STS) approach (104), using insects as the focus through which to
present a current ecological or environmental problem. On the high school
level, materials that emphasize insects to foster investigative skills focus on
scientific method and development of a controlled experiment (49, 50). Diverse
and unusual investigations are available that relate arthropods to basic concepts
and theory from ecology, ethology, population genetics, and evolution (23, 48a,
146, 200).

Many teachers are uncomfortable with activities that may not have predictable
results, but giving students the opportunity for open-ended inquiry continues
to be a major goal of science educators (6, 174, 247). A widely used open-ended inquiry exercise asks students to design and conduct an investigation in which pillbugs or mealworms choose between two conditions (3, 23, 28, 118, 121, 177, 204, 214, 231, 256). Other open-ended inquiries (23) include color perception in honeybees, assortative mating in soldier beetles, and oviposition in cabbage butterflies and bean beetles. A recent successful example involves harmless parasitic insects introduced to sixth grade students as a “mystery organism.” After determining the creatures’ life cycle, identity, and general behavior, students define questions and problems, then conduct experiments to investigate them. Students have voiced positive attitudes toward the project, the organism, and the freedom they felt in designing their own experiments, and they have demonstrated a wide range of higher order cognitive process skills and attributes characteristic of real scientists (77).

Holistic Instruction

Also called cross-disciplinary instruction or an integrated curriculum, holistic instruction has been particularly popular at the elementary level (e.g. 85), combining scientific content with art, literature, drama, music, dance, history, and mathematics. Teachers and curricula draw on an extensive children’s literature on insects (38, 55, 65, 94, 250), including poetry (80, 189a). The children’s classic *Grouchy Ladybugs* (35) provides an example of the use of literature as a springboard for integrated science, language arts, and social studies (29). Writing skills are included in “Build a Bug” exercises; students not only design the insect, but describe the habitat in which their creation lives, provide a scientific name, and write a story about a day in its life (89, 187, 207, 221, 236).

Increasingly, science curricular materials are being designed and marketed as entire sets (e.g. 82, 207). Many of these include not only holistic but also multicultural and cross-cultural activities (178), particularly with Hispanic and Native American themes (88). The *Keepers of the Earth* (31, 32) merges Native American lore with science, literature, and culture. Folklore may also be included (137). Several curricula are available in Spanish versions (178).

CLASSROOM FAVORITES

Educators have only begun to tap the immense variety of suitable arthropods for teaching students from kindergarten through high school. Although activities are many, the insect species they represent are disproportionately few.

**Lepidoptera: Butterflies and Silkworms**

First cultured over 3000 years ago, silkworm moths (43, 109) are a common classroom lepidopteran most often used to demonstrate change and
metamorphosis (3, 84, 231). Easily reared in the classroom, the painted lady butterfly is very popular for hands-on life cycle and metamorphosis studies (14, 34, 63, 69, 82, 207, 250). The monarch butterfly—state butterfly of Vermont, state insect of Illinois and Alabama, and proposed as the National Insect for the United States (237)—is the subject of a number of written educational materials, both popular (24, 86, 126, 134, 228) and scientific (143, 203, 248, 266). Habitat conservation is an important issue often raised in studying them (203) because deforestation threatens to endanger the monarch’s overwintering sites in Mexico.

Hymenoptera: Honeybees, Parasitic Wasps, and Ants

Honeybees are featured in many elementary level books (e.g. 70, 244) and precollege nonfiction (e.g. 157). The GE MS activity “Buzzing a Hive” (64) provides an excellent elementary level unit on bee biology and communication that integrates various subjects. A waggle-dance activity for elementary students is another avenue for teaching insect communication (47). World Wide Web browsers also can find abundant information on beekeeping.

A tiny wasp deployed against tomato/tobacco hornworm caterpillars (Trichogramma spp.) has been used in high school and college laboratories to demonstrate principles of biological control (172). One interesting laboratory activity examines the effects of population density on oviposition behavior (50). At the University of Georgia, another parasitic wasp (Melittobia digitata, called WOWBugs) is the subject of curricular materials currently under development to teach biological concepts to middle grade students (147). Parasitic in the nests of a number of solitary wasps and bees, in the classroom the WOWBug can be induced to feed and develop on an artificial diet.

Many children’s first close-up exposure to insects comes through observing an ant farm. These ubiquitous insects have been the subject of literally hundreds of fiction and nonfiction books (55, 75). Simple keys are available to identify the ants most commonly collected by teachers and students (53, 249); keys to genera worldwide (19, 106) are comprehensive but somewhat cumbersome for precollege use. Classroom rearing is relatively straightforward (4, 15, 54, 87, 254). Many excellent additional resources (e.g. 125), including holistic curricular materials (101, 137), are available. Ants also star in many secondary to college level activities; chemical communication (17, 145) and maze learning (1) are two examples.

Coleoptera: Ladybugs and Mealworms

Ladybugs are easily obtained by simply asking students to collect them; every child knows what they look like. For teachers who prefer to order them, garden supply houses are cheaper sources than biological supply companies. MacRae
(141) provides a picture key to identify common field-collected species. The GEMS materials include a holistic preschool and early primary unit on ladybugs (65); although 200 reviewers are listed by name, not one of the reviewers is an entomologist. Other more strictly science-oriented activities include studies of dispersal and predation (118, 142). Investigation of predator-prey relationships and population dynamics in aphids (50) would be a natural tie-in.

Mealworms, widely used in the classroom, are sold in bait and pet stores as food for frogs, lizards, and other carnivores. Actually, they are larvae of the darkling beetle *Tenebrio molitor*. Mealworms thrive under conditions best described as benign neglect (84, 92, 121, 139, 231). The main focus of most curricular material is on exploratory behavior and choices (3, 82, 92, 118, 121, 231).

One of the earliest comprehensive integrated curricular units featured mealworms (256): its contents have been so widely borrowed and adapted to science curricula for elementary and middle grades that no attempt is made to list these many adaptations here. For secondary level students, an investigation of pheromone communication in adult mealworm beetles (219) is very effective and adaptable, as are experimental investigations of the effects of two environmental pollutants, coal fly ash and second-hand smoke, on these insects (50). Another high school activity examines adult darkling beetle internal morphology and digestion (194).

**Diptera: Fruit Flies and Mosquitoes**

Biological supply companies offer a broad array of mutant stocks of *Drosophila* species, the undeniable workhorses of genetic investigation. Fruit flies also can be easily caught in a homemade trap (118). Genetic-cross activities are so standard in high school and college textbooks that no attempt will be made to review them here. Because the entire life cycle, from parent to adult offspring, takes only about two weeks, fruit flies easily can be used for life cycle studies in the classroom (118, 121). Fruit flies also have been used to demonstrate courtship behavior (184, 200), odor discrimination/conditioning (235), and biocides in natural plant extracts (50).

A teacher enhancement program in biology at the University of Wisconsin at Madison has combined the efforts of scientists and teachers to produce *Mosquitoes in the Classroom* (232), an unusually comprehensive yet appealing blend of holistic instruction and scientific accuracy for elementary and middle grade students. An earlier Elementary Science Study (ESS) unit on mosquitoes (68) remains useful for elementary level. A high school activity involves investigations of the effects of temperature and of environmental tobacco smoke on the development of mosquito larvae (50).
Orthoptera: Crickets, Mantises, and Cockroaches

Crickets are easy to catch (16, 118), buy locally as fish bait, or culture in the classroom (15, 92, 121, 139, 213, 220, 227, 231, 255). They are commonly used in the classroom to demonstrate aggression, territoriality, and auditory communication (17, 118, 144, 200). Books (e.g. 196, 265) and activities (12, 82, 118) for younger students include a variety of observations and choice tests.

Mantises have been the subject of many children’s books (e.g. 42, 103, 127) and of experiments to investigate prey recognition, habitat choice, climbing behavior, and more (118). They can be raised from an egg case (84, 92, 121), collected outside, or ordered from a garden supply company, and they will feed on anything from mealworms and crickets to fruit flies. Mantises make excellent subjects for studies of grooming behavior (13).

Cowles (44) is an informative resource on cockroaches. A relative newcomer to biological supply companies is the Madagascar hissing cockroach (48). Larger but more sluggish than its domestic relatives, this classroom-friendly insect vocalizes by expelling air through its respiratory spiracles. Communication (50), dominance hierarchies (67), and maze learning (182) are possible activities.

Other Close Relatives: Spiders

Many children’s books and activity resources feature spiders (3, 15, 92, 105, 223, 226, 250). Although there are thousands of species of spiders, most classroom activities require little more identification than to a general, broad category (113, 135). Orb weavers and tarantulas are available from biological supply houses, but many spiders are so common that it is easy to catch them oneself (118). Only the black widow and the brown recluse have dangerous bites; the others are either too timid or small to bite, or at worse have a bite that is equivalent to an insect sting. All can be avoided by simply keeping one’s hands out of dark places into which one cannot see.

ACCESSING YOUR ENVIRONMENTS

The Outdoor Classroom

Many teachers hesitate to use local and schoolyard surroundings, primarily because of concerns regarding discipline, control of students, and potential liability. As a result, more than 80% of seventh and eighth graders report never going on field trips with their science classes (170). However, a number of excellent general resources that include insects exist and can assist teachers willing to venture into the schoolyard (46, 90, 102, 136, 205, 217, 225, 234). Some are aimed specifically at city schools (102, 209).
Insect field biology is specifically targeted by Hall (91). The school environs can provide the setting for various long-term or repeated outdoor entomology projects (25, 61, 239). A number of seasonally organized general guides are targeted to the backyard student naturalist (22, 115, 116, 218, 234).

Schools located near water have additional field sites. With the help of some excellent guides (40, 151, 153, 189, 191, 192), students can easily learn to identify the major macroinvertebrates most commonly encountered and can undertake a variety of ecological exercises (48a). Aquatic insects also make excellent laboratory organisms (62, 97, 165–67).

Indoor Ecosystems
Given their relatively small size, insects easily lend themselves to environmental education undertaken wholly in the classroom. A 16-lesson unit for fifth graders, in which students construct, observe, and discuss both land and water ecosystems, introduces crickets and pillbugs to help students understand the web of relationships that link plants and animals to their environment (175). Mud dauber wasp nests, a microcommunity entirely composed of arthropods, are the focus of an adaptable activity (149). Because each nest is a unique habitat, the activity has a certain inherent unpredictability that instills a sense of doing “real” science.

Simple ecosystems also can be studied under greenhouse conditions. Investigations using aphids (138, 172) can serve as a springboard for discussion of biological control and pest management. Other biological control activities have been developed for studies of parasitic wasps at the high school level (50) and ladybugs at the primary school level (65).

Community Resources
Whether it be a trip to a university laboratory, a stop at the local bait shop, a visit to or from the local exterminator, an exhibit at the local zoo or nature center, or simply an excursion into the schoolyard, the world of informal learning situations outside the classroom serves the science teacher well. A current trend in entomology education is the creation and use of insect zoos (39, 156, 158, 210).

Some organizations have instituted outreach programs, bringing to the schools an assortment of live and preserved specimens that students may handle, videotapes and photographs of insects, and trained staff who can provide accurate factual information. Universities, nature centers, and some public schools also offer open houses and other special programs (60) where students and their family members are entertained by a variety of interactive activities; their goal is to provide an entertaining environment in which a large number of people can be exposed to the positive aspects of insects (123).
INSTRUCTIONAL RESOURCES

Observation and collection are common first steps for both teachers and students. A number of educational resources at the elementary school level emphasize observation and collecting skills (52, 152, 218, 238). These activities usually lead to a search for more information, and teachers often ask which book to buy as a class or personal book on insects. There is no single best answer, for it depends upon grade level, purpose for which the book will be used, and individual preferences.

Identification Guides
Many teachers begin with a basic field guide, for the first question asked about an insect is usually “what is it?” In practice, given that there are some one to ten million species of insects on the planet (261), this first question may be one of the most difficult to answer.

A number of illustrated handbooks help to provide names for the commonest insects, and well-prepared teachers at all levels should have a few on hand. Widely used standard insect field guides for North America include Borror & White (20), Zim & Cottam (267), and McGavin (154). Guides by Arnett & Jacques (9) and Milne & Milne (161) are particularly helpful because of the extensive use of color photographs. Other older books can still be useful (140). More specific identification guides are available for spiders and their relatives (113, 135); caterpillars (264), common butterflies, and moths (164, 186, 202, 252); aquatic insects (133, 151, 192); ants (53, 106); stored product insects (168); and beetles (260).

Several field guides are targeted specifically for children (57, 59, 118, 131, 229). Dunn (57) provides a concise reference for insect identification of particular use for Science Olympiad, 4-H, and similar programs, and he also provides an extensive bibliography.

Curricular Resources
How can a teacher find curricular materials that use a particular insect or teach a specific concept through the use of insects? The National Science Resources Center, an affiliate of the Smithsonian Institution and the National Academy of Sciences, has compiled an annotated guide to selected curricular resources for elementary science education (178); all are consonant with recommendations in the new National Science Education Standards (174) developed by the National Research Council of the National Academy of Sciences.

State and county cooperative extension offices have a myriad of free publications on everything from turf pests to honeybee husbandry. The pest control industry also is increasingly supportive of the need for educational materials
on insects. For example, Orkin Pest Control is a sponsor of the Smithsonian
Insect Zoo and has produced a classroom activity guide (187).

Supplemental Reading
If “what is it?” is the first question, then “what does it do?” is undoubtedly
the second. Many general works (73, 110, 148, 169, 233, 258) are also quite
readable classroom references. At a slightly more advanced level, college texts
(191, 193, 212, 246) are good choices. A teacher might consider presenting
a humorous look at things insects accomplished first (5) or an eclectic mix of
highly readable entomological vignettes (2) ranging from the contributions of
amateurs to insects on stamps and in the Bible. Entertaining books on insect
study (14a, 14b, 51, 71, 242) and biographies of prominent entomologists (99,
262) also are good choices.

Natural history museums and similar organizations also produce regular
newsletters or other publications (179, 198, 199) that feature insects or other
arthropods. Available at modest cost, these often include suggestions for chil-
dren’s activities. Examples include Backyard BUGwatching (Sonoran Arthro-
pod Studies, Inc., Tucson, AZ), Nature Naturally (Callaway Gardens, Pine
Mountain, GA), Wings (Xerces Society, Portland, OR), and Beeswax (Entomo-
logical Society of America, Lanham, MD).

Sources of Living Insects
Biological supply companies (58) routinely sell living cultures of everything
from cockroaches to butterflies, together with suitable artificial diets or media,
and instructions. However, the cost of such materials tends to be relatively high
for most teachers’ budgets.

 There are many other less expensive sources (56). Mealworms, crickets,
and wax worms are available from many bait shops at bargain prices, as stated
above. Insects used for biological control (e.g. mantises, ladybugs, parasitic
wasps) can be purchased in quantity through the catalogs of various nurseries.
Collecting insects in the field is the most inexpensive of all. Many field guides
(e.g. 20, 41, 140) include brief summaries of various collection techniques,
and activity books (e.g. 38, 118) often include brief sections on finding and
capturing insects.

Rearing and Maintaining Classroom Insects
The maintenance of insects in the classroom is hardly new (41, 220), but for
many teachers, it remains a major challenge and an often frustrating experience.
Classroom air tends to be extremely dry, particularly because of heating during
the winter season, and because arthropod surface area to volume ratios are
extremely high, desiccation is a major threat to rearing success (56).
A wealth of information on insect rearing has been compiled through the Young Entomologists' Society (56), but except for some rather technical references (e.g. 230), few materials are devoted exclusively to insect rearing. A standard classroom reference since 1937 has been *Culture Methods for Invertebrate Animals* (139). Other rearing descriptions for common classroom insects (84, 121, 171, 188, 220, 227, 231) include information on natural history, housing, diet, handling, observations, and simple activities that are adaptable to most grade levels. *The Carolina Arthropods Manual* (37) provides culturing information for most living arthropods shipped by biological supply houses. The *Keeping Minibeasts* series (253–55) includes rearing information for beetles, butterflies and moths, spiders, grasshoppers, crickets, and ants. Specialty publications detail relevant techniques for maintaining stick insects (81), tarantulas (263), butterflies and moths (83, 251), mosquitoes (68, 232), midges (97), and hissing cockroaches (48).

Newsletters are also rich sources of information. One of the more unusual is the *Food Insects Newsletter* (University of Wisconsin Entomology Department, Madison WI). *Frass*, a forum for anyone interested in insect rearing, is now available electronically on the Internet. A catalog of other entomological newsletters (58), many of which are on the Internet, indicates those that cater to other specific interests, from fleas to caddisflies.

**Finding Equipment and Supplies**

Everything a teacher needs to rear and maintain classroom insects is available from the major biological supply companies. A less expensive, but more time consuming, alternative is to build and “scrounge.” Although targeted for K–3 (i.e. 5- to 9-year-olds), the information sheets and appendices in *Using Live Insects in Elementary Classrooms* (38) are superb and adaptable to any level; these materials detail information on finding and collecting arthropods, keeping live arthropods in the classroom, and constructing inexpensive containers for housing various species.

Construction details for simple cages suitable for rearing and observing insects are available from several sources (15, 26, 94, 119, 160). Information on suppliers of entomological equipment and supplies is available as a compilation (58).

**CONCLUSION**

Although still greatly underrepresented in relation to their numbers and diversity, from this review it should be evident that insects occupy an important niche in the precollege (and particularly the elementary school) curriculum. However, with few notable exceptions, most of the literature on insects produced for
K–12 educators is authored by writers, educators, and teachers, with little or no input from professional entomologists. This reinforces survey results showing that in general, professional scientists are not effectively communicating the importance of science to North American youth. Rather, amateurs are fulfilling this vital role, and by and large they do not perceive professionals as interested in sharing this work with them (145a).

Research has firmly established the fact that interest in science drops as children progress through school (229a) and that this drop is particularly dramatic during the middle and high school years (239a). It needn’t be this way. Many of the best teachers and students are eager for information about insects. They are warmly receptive to outreach activities ranging from simple classroom visits to special events such as insect zoos, bug fests, and the like. A survey of adult amateur entomologists found that four out of five respondents had become interested in entomology when they were children (145a); a similar percentage almost certainly applies among working scientists.

Thus, we conclude with a plea to our fellow scientists to take a more pro-active role in the educational process. All too many in our profession treat science as if it were an elite subject for an elite population (143a). Opportunities abound for those with vision to reach beyond the narrow confines of academia and share their entomological knowledge and enthusiasm with those upon whom our future depends. The grins, gasps, and exclamations of wide-eyed students enthralled by such experiences will be ample reward for the modest effort required.

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