have merit. However, an examination of the course topics, laboratory exercises, and assessment tools reveals a much different story (Table 1). A forensic entomology course can serve as an excellent vehicle for exploring key concepts in biology, ecology, and entomology by engaging student interests. The course I have developed explores many of the same concepts that a traditional entomology course includes (e.g., succession, competition, parasitism/predation, growth and development, environmental influences, seasonal adaptations, morphology, and taxonomy), as well as a small insect collection with identifications that are much more specific to the topic. For example, all Dipteran and Coleopteran specimens are required to be identified to genus and species, while any other insects should be identified to family. Identification specificity is due to the fact that collections are used in the context of crime scene processing and expert witness reports, and thus the insects represent physical evidence obtained from mock crime scenes set up around campus. The latter is the key to motivating students in tedious taxonomic work; they enjoy the application to mock crime scenes, a feature that seems to be universal to high school students and undergraduates (Schoenly et al. 2006). Involvement in real-world projects or authentic enterprise is also an important experience for students to develop their own identity as scientists and making informed decisions about career paths (Thiry et al. 2011).

Conclusions

The primary goal of using forensic entomology to teach undergraduates is not to convert all enrollees to entomology. No, the world can only stomach so many of us at a time! Rather, the discipline serves as a thematic framework for engaging otherwise disinterested students into topics and concepts essential for broadly trained biologists. Does the forensic entomology curriculum work? If the desired outcomes are increased student interest, motivation, and learning, the answer is unequivocally yes. Subsequent student enrollments in my general entomology course and involvement in research have also increased, an indication of sustained student interest in insect biology. Many other conceptual themes could also be well suited for this type of curricular design, and should be based on the interests and backgrounds of students and instructors. Hearing students comment to their peers that they cannot wait to take forensic entomology is not only gratifying, but also bodes well for the future of our discipline.

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Table 1. Example content from the lecture and laboratory components of an undergraduate forensic entomology course taught at Loyola University Maryland.

Lecture	Laboratory
Insect use in legal investigations	Examination of general external and internal morphology
Short introduction to morphology, growth, and development	Morphological characters of forensically important flies and beetles
Necrophagous fly reproduction	Rearing forensically important species
Chemical communication and signaling in carrion communities	Collection and preservation techniques
Natural and artificial influences on succession	Group case analyses
Applied topics of insects and death, abuse/neglect, terrorism	Examination of physical decomposition under a range of conditions
Modeling insect growth, degree days, and estimating the postmortem interval	Field trip to morgue
Specialized topics on forensic archaeoentomology and deadly insects	Crime scene investigation: A multi-week capstone project using mock crime scenes for processing, analyses, and presentation

INSTANT SYMPOSIUM 8

Stimulating Curiosity and Engagement with Insects Beyond the College Classroom Through Citizen Science

DEREK W. ROSENBERGER AND BRIAN H. AUKEMA

Many professional entomologists were first introduced to the study of insects through a college biology course, yet little work has been published demonstrating effective means of stimulating curiosity and engagement with insects beyond such first exposures. At many small liberal arts colleges, a single introductory course in entomology or invertebrate biology may be all that is offered. This limitation increases a need to understand effective pedagogies that stimulate further engagement of students.

Undergraduate research experiences are particularly effective at stimulating the pursuit of graduate programs in science-related fields post-graduation (Lopatto 2007). While we often perceive research experiences to be grounded behind a lab bench, course-based undergraduate research experiences can also promote continued engagement with science (reviewed in Corwin et al. 2015). However, instructors of introductory courses are often limited in time and resources, making facilitation of such experiences difficult. Thus, engagement in authentic research—one of the more effective tools for developing future scientists—is often precluded from a venue where future entomologists are likely to be birthed: the introductory college classroom.

Integrating citizen science into introductory science courses may be one means of addressing this issue (Vitone et al. 2016), and can be a win-win for students, instructors, and researchers. Citizen science can be defined as "the active engagement of the public in scientific research projects to address real-world problems" (Wiggins and Crowston 2011). A slight modification of this definition is well-suited for student learning outcomes within a course syllabus: "Students in this course will actively engage in scientific research projects to address real-world problems."

In practice, researchers have long collaborated with volunteers to collect data. In recent years, many researchers have turned to formalized citizen-science projects to recruit help. Some excellent examples of such projects, within the field of entomology, can be found on Scistarter.com and the Xerces Society. Projects cover a range of areas within entomology and are often focused on conservation and species monitoring (Johansen and Auger 2013). While such projects have great potential for supplying valuable data to researchers, recruitment of large numbers of participants can be difficult (Vitone et al. 2016).

Here, we share our success in integrating two citizen-science projects into three different courses at different institutions: Invertebrate Biology (BIO 308) at Bethel University (MN), Forest and Shade Tree Entomology (ENT 4251) at the University of Minnesota (MN), and Issues in Environmental Science (BIO 314) at Wheaton College (IL). Each investigation-type project (Wiggins and Crowston 2011) has taken one of two forms: a partnership with a state agency, brought into the classroom (Case Study 1), or the utilization of an established citizen-science program (Case Study 2). Partnerships with state agencies in non-formal citizen-science projects can be particularly rewarding for students, and provide networking and résumé-building opportunities. However, such projects are likely limited to the course, and require significant management and quality control on the part of the instructor. Conversely, student participation in formalized citizen-science programs, often with user-friendly websites and established protocols, can continue following completion of the course. We present two case studies as examples of ways citizen-science projects can be integrated into science courses.

Table 1. Example project outlines of how the two projects were integrated into laboratory sessions. Other bycatch or monitoring projects could utilize similar frameworks.

Case Study 1: Bycatch Assessment Project
Laboratory session 1
An entomologist from the Minnesota Department of Agriculture introduces invasive insect monitoring in Minnesota.
The instructor introduces the project, forms groups based on trap regions, and discusses project purposes and research questions.
The instructor shows examples of target insects and provides data sheets and materials.
Students sort each collection into target and non-target insects. Sorted bags are labeled and stored.
The instructor works closely with the students to identify target insect groups.
Laboratory session 2
Students finish sorting insects.
Students submit results to the instructor.
Groups begin working on the lab write-up (introduction, methods, results, implications).
Laboratory session 3
Each group presents results from the region they assessed.
The instructor presents consolidated results and implications are discussed by the class.
Results are shared with the Minnesota Department of Agriculture.
Case Study 2: Campus Bark Beetle Monitoring Project
Laboratory session 1
The instructor introduces the project, forms groups, and discusses project research questions.
Groups construct, distribute, and bait traps in transects around campus.
Students check traps daily for one or two weeks and store samples in a freezer.
Laboratory session 2
Students assess trap catch and determine presence and quantity of bark beetles.
Students submit collection results to the instructor.
Groups begin working on the lab write-up (introduction, methods, results, implications).
All bark beetles are sent to Backyard Bark Beetles to be identified.
Laboratory session 3
Each group presents results to the class.
The instructor presents consolidated results. Implications of findings are discussed by the class.

Case Study 1

The Minnesota Department of Agriculture (MDA) is responsible for the monitoring of invasive species in Minnesota. One program deploys traps baited with aggregation pheromones throughout the pine regions of the state to monitor for potential introductions of mountain pine beetle (*Dendroctonus ponderosae*), a bark beetle native in western North America. Resource managers and regulating officials are also interested in whether potential predators or competitors of existing native bark beetles would respond to aggregation pheromones produced by mountain pine beetle, if the insect were to arrive in the region. However, MDA time and resources were not allocated beyond monitoring for the mountain pine beetle. Thus, in BIO 308 and ENT 4251, we partnered with the MDA to process and analyze the bycatch from traps for potential predators and competitors of the mountain pine beetle (Table 1).

There were three principal learning outcomes of this project. First, the students experienced authentic scientific discovery as they collected and analyzed data to address a real-world question with

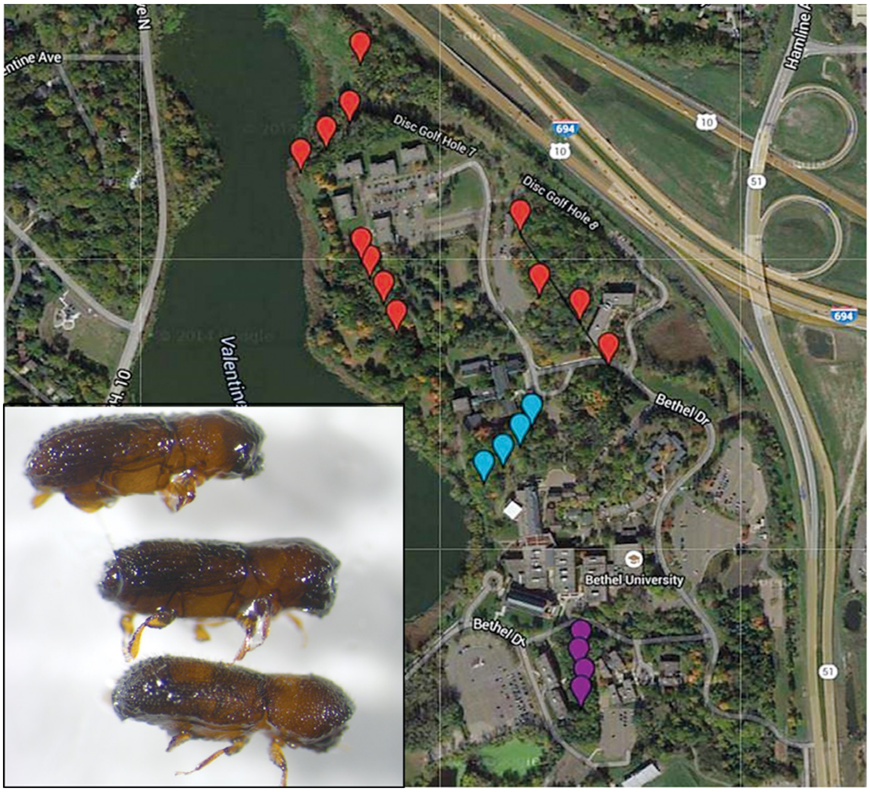

Fig. 1. Five transects of four traps (colored points) established by groups of students on the Bethel University (MN) campus to monitor for bark beetles during the bark beetle monitoring project (Case Study 2). Students used Google Maps to record trap locations. The inset image shows fruit tree pinhole borers (*Xyleborinus saxesenii*) caught in student traps. These captures represented the first record of this insect in the state of Minnesota.

an unknown answer. Second, students gained a familiarity with insect diversity by spending two lab periods sorting through the diversity of insects found in bycatch and identifying different groups. Students handled insects from many different orders and families, including many species that few people encounter. Third, students gained presentation and communication skills by writing laboratory reports and orally presenting their work to classmates. Students responded positively to this project and the chance to interact with a professional entomologist from the MDA. Several students inquired about further opportunities for involvement, including potential summer positions with the MDA.

Case Study 2

Backyard Bark Beetles (www.backyardbarkbeetles.org) is a formalized citizen-science project coordinated by the Hulcr lab at the University of Florida. This project is designed to monitor potentially invasive bark beetles and assess distributions. Citizen scientists engage in this project by monitoring a homemade window trap made from an upside-down two-liter soft-drink bottle with one side removed. Hand sanitizer, which is typically 70% ethanol, is placed in the bottom of the trap, where it serves both as an attractant (emulating a stressed tree) and preservative. Traps are checked for bark beetles and refilled daily. Samples are sent to Backyard Bark Beetles to be identified.

This project was effectively integrated into all three courses during modules focused on insect diversity or invasive species (Table 1). Students were motivated by the recognition that the abundance and identity of the various species of bark beetles on campus was unknown to science. As such, if students did not monitor for the presence of invasive species, potential new introductions could go undetected. Indeed, the efforts of the students in BIO 308 resulted in the first detection of the fruit-tree pinhole borer, *Xyleborinus saxesenii* (Ratzeburg) (Coleoptera: Curculionidae), in Minnesota in April 2015 (Fig. 1). This ambrosia beetle was previously unknown to state agencies such as the MDA and the Department of Natural Resources, and we could not find previous records in the literature or the University of Minnesota Insect Museum.

Students completed evaluations that asked about interests prior to and following involvement in the campus bark beetle monitoring project. A majority of students expressed that they were interested in engaging in additional citizen-science projects in the future after having been involved in the project. In addition, a majority of the science majors responded that they would be interested in engaging in insect-related research in the future after having participated in this project (D. Rosenberger, unpublished data).

These case studies offer examples of how the use of citizen-science projects as authentic course-based undergraduate research experiences can be valuable for researchers, instructors, and students. Course-based citizen science offers researchers and instructors opportunities to engage students in authentic research experiences, achieving both scientific and educational goals. The accessibility of formalized projects provides students the opportunity to continue their engagement in entomological research beyond the classroom. Thus, this initial engagement could be the first step towards a life-long interest or career in entomology. Future work should seek to quantify such outcomes and investigate incorporation of course-based citizen science into disciplines beyond entomology.

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