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Insects as Educational Tools: An Online Course Teaching the Use of Insects as Instructional Tools

Douglas A. Golick and Tiffany M. Heng-Moss

Publication of the 1996 National Science Education Standards (NSES) initiated a push to transform science education by engaging K-12 students in active learning through inquiry-based teaching (National Research Council, 1996). Students need opportunities to construct knowledge by asking questions, developing hypotheses, collecting and analyzing data, and interpreting and communicating results. Inquiry teaching has been shown to improve students' attitudes toward science, enhance their performance, and promote scientific literacy (Hauray, 1993; Lindberg, 1990; Mattheis and Nakayama, 1988; Rakow, 1986).

Providing both pre- and in-service teachers with courses and professional development programs that promote inquiry teaching are vital to teacher education (National Research Council, 2000). Although many teachers have encountered inquiry instruction, either through pre-professional education or during professional development, some still need in-service experiences, particularly K-6 teachers.

The majority of elementary teachers have taken few science content courses. In a national survey, Fulp (2002) found that 42% of elementary teachers had completed four or fewer semesters of science coursework, and fewer than 30% of all elementary teachers in the survey felt well prepared to teach science. In a survey of 57 Nebraska elementary teachers participating in a statewide elementary science institute, 61% indicated they had taken three or fewer hours of science courses as undergraduates. Only 4% of teachers indicated taking six or more hours of science courses as undergraduates. Therefore, most elementary teachers feel inadequate and anxious about teaching science (Pedersen and McCurdy, 1992; Cox and Carpenter, 1991; Sutton et al., 2009).

Many programs exist to improve in-



A boy examines a climbing walking stick.

quiry instruction using insects as model organisms and pairing entomology content with science inquiry techniques; these include workshops, professional development, and curricula development. However, few college-level courses offer this pairing. A review of the literature and Web-based resources identified five courses integrating entomology content with inquiry teaching strategies for pre- and in-service teachers (Haefner, Freidrichsen, and Saul 2006; Leigh 2000; Texas A&M, April 6, 2012; University of Arizona (a), April 6, 2012; University of Arizona (b), April 6, 2012). Only two were offered as graduate-level courses (Leigh 2000; University of Arizona (b), 2012). None were offered online.

Since 2003, the University of Nebraska at Lincoln (UNL) has offered *Insects as Educational Tools* (ENTO 810) as an online course through UNL's Master of Science in Entomology program. Many K-12 educators enroll in this course, which appeals to them because it explores the use of insects as model organisms for teaching science and ad-

ressing national science standards. ENTO 810 is included in the Insect Biology for Educators Certificate program offered by the University of Nebraska-Lincoln (<http://tinyurl.com/phb99r6>). It is also open to informal educators, and to graduate students enrolled in the online M.S. program in Entomology. These students learn about benefits of teaching with insects in informal settings (e.g., outreach events) or professionally (e.g., training).

ENTO 810 is team-taught, uniquely combining the expertise of an entomologist and a teacher educator. Together, they expand the range of topics to include comprehensive coverage of entomology content, science processes, pedagogical strategies, and curriculum development. During the course, students construct links between entomology content and inquiry-centered pedagogical approaches for teaching science.

Although this course could be designed and taught with another animal or plant system, insects are excellent model organisms because they share many biological processes with other organisms and they have a large impact on society (Center for Insect Science 1993). Unlike vertebrates, insects are generally inexpensive to purchase and maintain. Many insect species used for teaching can be collected locally (Kneidel 1993). Mass numbers of individuals are readily obtainable for experimental repetitions. Insects' short life cycles and predictable behaviors make observations easy—important in K-12 classrooms, where teachers often have limited time available for any particular topic. Insects are diverse, and their adaptability offers opportunities for a wide array of investigations (Matthews et al. 1996; Matthews et al. 1997). Paramount among their benefits, insects as research organisms usually involve fewer ethical concerns and restrictions than other animals.

Course Structure and Objectives

ENTO 810 is divided into three modules taught over 15 weeks. Successive modules build on learning objectives from previous modules; therefore, satisfactory completion of each module is integral to final learning outcomes. The instructional objectives of ENTO 810 are to enable students to:

- describe the diversity of insects and basics of insect biology
- classify and differentiate major insect groups
- give examples of beneficial and detrimental roles insects play in our lives
- utilize scientific methodology to make discoveries about living things
- teach guided inquiries using insects (i.e. inquiries in which the instructor provides students with a specific research question, but in which they have freedom to refine the question, select materials, and develop procedures)
- develop simple demonstrations and experiments to stimulate students' interest in insects and science

These goals target both novices and experts in the fields of entomology and teaching.

Course Modules

Module 1 focuses on entomology and science process content. Delivered over 5 weeks, this module provides an overview of insect biology, including the classification system, insect biology and behavior, reasons to study insects, and specific insects recommended for classroom use. Content is presented via eleven PowerPoint lectures with audio narration, targeting students new to the science of entomology. For students who have already taken an introductory entomology course, this module is a beneficial refresher.

An icebreaker exercise introduces students to the course and its supporting technology. Using the course's online discussion board, students post six nouns that describe themselves. Students are required to read their classmates' postings and reply to each other. This acquaints students with the course site discussion board tool, facilitates social interaction among students, and establishes an interactive online learning environment.

In Module 1, students complete a pre-reflection exercise (Figure 1) in which they answer a series of questions requiring them to reflect on their current understanding of insect biology, their general entomological knowledge, the processes of scientific inquiry, and their knowledge of teaching and pedagogy. They also host an insect pet to learn first-hand about insect life cycles, biology, and behaviors. A worksheet guides students through instructor-initiated inquiries with insects, providing hands-on discovery opportunities and experience with rearing live insects. These activities develop the students' science process skills and enable them to create an ethological sketch of their insects. This curriculum component is vital, because many students have limited prior experience with insects and varying levels of confidence in handling insects.

Student learning in Module 1 is evaluated via the pre-reflection exercise, the insect pet observation and behavioral activities, and online quizzes that cover key concepts from assigned readings and the 11 lectures. Students are allowed one attempt at each of the quizzes.

Module 2 focuses on science inquiry and the nature of science. Specific topics include the nature of science, the processes of inquiry as implemented by scientists and as applied by teachers, and hypothesis development. A key objective of this module is to provide students with experiences teaching science inquiry lessons as they progress through a series of eight guided inquiry lessons using insects. Students receive in-depth instruction in developing test-

able hypotheses. To help ENTO 810 students prepare for their teaching experiences, the lecture component is supplemented with a worksheet that guides them through the inquiry teaching process.

Guided inquiries were chosen instead of open inquiries, based on an assumption that guided inquiries are easier for teachers new to the inquiry teaching approach: they have structured, testable hypotheses and expected outcomes. Lesson plans are detailed enough to guide inexperienced teachers and include teaching tips to facilitate conduction of lessons. Examples of these lesson plans are available at <http://unlcms.unl.edu/ianr/entomology/k12>.

To successfully complete Module 2, ENTO 810 students must find a student audience and teach two different inquiry lessons. Student audiences can include formal classrooms, 4-H groups, museum visitors, after-school programs, or their own children. Occasionally, where child audiences are hard to find (e.g. for ENTO 810 students serving overseas), students choose an adult audience.

For each lesson they teach, ENTO 810 students must complete the "Classroom Instruction and Evaluation of Inquiry Lesson" worksheet. This worksheet requires them to provide information on the teaching methods used, details about how they conducted the lesson, the inquiry processes used in the lesson, and their assessment of student learning. The worksheet establishes a record of the students' teaching, and gives both course instructors an opportunity to provide in-depth feedback to

Figure 1. Pre- and Post-Reflection Exercise

1. Describe your current understanding of science inquiry. What does it mean to you? What are the steps of the process?
2. Describe your current understanding of entomology and insect biology. For example, do you know the major insect orders? If so, what are they? Describe the structure and function of the insect body parts. Can you list ways insects communicate? Where can insects be found? How do they develop from immature to adults?
3. What do you think the most challenging aspect(s) of teaching the guided inquiries in Module 2 will be?
4. An important part of learning is about making connections between new and old concepts, to form understanding. Occasionally, we consciously recognize these moments of connection. What strategies will you use to connect the things you will learn in this course to your prior understanding of teaching, entomology, and insect biology? What strategies will you use to change your previous misconceptions and form new, better-informed opinions?
5. What do you look forward to learning about insects and teaching with insects in this class?

each student on each of their two lessons. These worksheets are submitted via Blackboard's assignment feature and the first worksheet is returned to the students a week before the second worksheet is due. Thus, students receive constructive comments they can use to improve their teaching experience for the second guided inquiry lesson.

Students complete a post-reflection exercise at the end of Module 2. This exercise builds on questions in the pre-reflection exercise. We use a guided written reflection with prompts to assist students; this facilitates students in making judgments about their learning and self-evaluation. Students complete this exercise in the 10th week of the semester. Giving the reflection exercise at this point rather than at the end provides students time to reflect on their learning and make adaptive adjustments in their learning and teaching.

Module 3 requires students to incorporate content knowledge from Module 1 with teaching experiences from Module 2 to generate two unique insect-based inquiry lessons for PK-12.

The first lesson plan may be less refined than the second. Students receive detailed feedback on their first lesson plan, and use this feedback to improve their second lesson plan.

Each lesson plan must start with a testable hypothesis. Other components of each lesson plan include the targeted age level; materials (including where to obtain insects) and methods; relevant background information; KWL prompts (what you know, what you want to learn, and what you learned), and an assessment plan. ENTO 810 students are assessed on their ability to create practical lessons that may be easily understood by PK-12 teachers. Student-created lesson plans range from expansions of the course's guided inquiry lessons to novel ideas.

Students are graded on the extent of their lessons' originality. Ideally, student products should not duplicate either materials created by former students or the guided inquiries used in Module 2. Students are also graded on the quality and readability of their lessons. Assessment

These boys examine a millipede in preparation for a math lesson on arthropod body structures.



rubrics for lesson plans ask the following questions: Does the lesson work? Would it be a practical lesson to conduct for most classrooms? How appropriately is scientific methodology used to address the hypothesis? Lessons should be easy to read and provide relevant background information for teachers unfamiliar with insect biology and behavior. Lesson plans should be of publishable quality commensurate with those in the "How to Do It" section of the *American Biology Teacher* journal.

At the end of the course, ENTO 810 students complete a post-test, which evaluates their content learning and their application of learned material over the duration of the semester. The purpose is to assess changes in their understanding of entomology content, inquiry processes and application, and level of teaching confidence as a result of the course. Comparing the pre-and-post assessment results provides an indicator of each student's improved comprehension, application, and synthesis of information about entomology and inquiry. Students are asked to self-assess their ability to teach inquiry lessons using insects, and their likelihood of doing so after completing the course.

Methodology

We compared the pre- and post-tests to assess effectiveness of the course in achieving specific learning objectives. The pre-test (administered at the beginning of the course) contained questions on entomological concepts and science processes (inquiry). Insect biology questions were selected to address basic entomology concepts required to conduct project inquiries. The pre-test evaluation also included self-assessment

items to measure participants' perceived ability to incorporate science inquiry investigations in their classrooms.

The post-test evaluation was identical to the pre-test, with the exception of the following question: "Has your definition of science inquiry changed since the beginning of this course?" Test questions were designed to measure change in self-efficacy in using insects and the inquiry methodology in teaching. Therefore, post-tests were not administered until students had completely finished the course. (The pre- and post-tests were checked for content validity as reported in Golick et al. 2010.)

Results and Conclusions

ENTO 810 has been offered six times since 2003; a total of 103 students have completed the course. Of these, 59 completed all questions on the pre- and post-tests. Their results were included in this analysis. Of the 59 students, we tracked the professions of 50. Of these, 56.0% were in non-teaching professions; many of these "non-educators" were in the military, or in agricultural and pest control professions. Thirty-eight percent of the students were PK-12 teachers. The remaining 6.0% listed their profession as either extension or outreach coordinators. For the purpose of this paper, we list those stating teaching, extension, and outreach in the "educators" category, as the primary focus of their job is education.

Entomology Knowledge: There was no significant change in students' ability to distinguish an insect from other arthropods (McNemar's, $P=0.50$). Most students (96.6%) identified essential characteristics of insects (an exoskeleton, 3 body segments, and 3 pairs of legs). However, there was a significant change in the number of Entomology Knowledge Questions answered correctly from pre to post-test (Table 1).

Before and after the course, students used a Likert Scale to assess their insect biology knowledge in relation to their ability to teach science inquiry lessons using insects. This was used as an indicator of self-efficacy in teaching using insects. Precourse, 75.0% of non-educators responded that they "agreed to strongly agreed" that their "...current understanding of insect biology was such that they could effectively use in-

Table 1. Entomology Knowledge Questions

	Pre		Post		z	p
	M	SD	M	SD		
Three insect orders	2.56	0.970	2.86	0.571	2.173	0.05**
Three ways insects communicate	2.63	0.584	2.97	0.183	3.750	0.001**
Three insect social groups	2.85	0.485	2.95	0.222	1.508	NS

NS, **, ***, Non-significant or significant at P=0.05, 0.01, or 0.001, respectively using Wilcoxon signed-ranks test

Table 2. Science Inquiry Knowledge Questions Change Pre- to Post-Course

	WI W2	RT W2	RT R2	WI R2	χ ²	P
Testable Hypothesis	20.34%	8.47%	38.98%	32.20%	7.04	0.01**
Best Science Inquiry Example	23.73%	8.47%	18.64%	49.15%	15.56	0.001***

WI = Wrong, Pre-Course; W2 = Wrong, Post-Course; R1 = Right, Pre-Course; R2 = Right, Post-Course. NS, **, ***, Non-significant or significant at P=0.05, 0.01, or 0.001, respectively using McNemar Tests, N = 59

Table 3. Science Inquiry Definition

	Non-Educators		Educators	
	Yes	No	Yes	No
"As a result of this course my definition of science as inquiry has changed."	84.2%	15.8%	78.6%	21.4%

Table 4. Science Inquiry Practice

	Non-Educators		Educators	
	Pre	Post	Pre	Post
"My current level of science inquiry understanding is such that I can effectively incorporate inquiry activities into my classroom or job."	64.3%	96.4%	68.4%	91.9%
"As a result of the course, I am likely to incorporate inquiry with insects into my curriculum or job."	NA	39.0%	NA	94.0%

Results reported for % of respondents answering "Agree to Strongly Agree" on Likert scale

sects in science inquiry lessons." Post course, 89.3% responded that they "agreed to strongly agreed." For educator students, 59.1% "agreed to strongly agreed" with the statement precourse, and 90.9% "agreed to strongly agreed" with the statement post-course.

Science Inquiry Knowledge and Practice: Students' knowledge and understanding of inquiry-based pedagogy improved as a result of the course. For the six steps of the inquiry process, there was a positive change in the number of correctly identified inquiry steps (P=0.001, z=5.839) that students listed pre-test (M=4.12, SD=1.176) compared with post-test (M=5.51, SD=0.704). There was a positive change in the number of students correctly identifying a testable hypothesis and the best example of an inquiry investigation (Table 2). At the end of the course, participants responded "yes" or "no" to the statement: "As a result of this course, my definition of science inquiry has changed" (Table 3).

Students were also asked to assess their science inquiry knowledge in relation to their ability to teach inquiry-based lessons both before and after the class. This measure was used as an in-

dicator of confidence in teaching using inquiry techniques (Table 4).

Students were asked to what extent they agreed with the statement: "As a result of the course, I am likely to incorporate inquiry with insects into my curriculum or job" (Table 4).

These evaluation summaries indicate that the course successfully stimulated interest in both insects and inquiry-based learning experiences. In general, students reported increased knowledge of inquiry, and stated that they planned to include more science inquiry lessons using insects as a result of the course. Educators and non-educators both improved their understanding of inquiry science along with their knowledge of insect biology. Students reported that their confidence in teaching with insects improved as a result of the course.

Conclusions: Based upon increasing enrollment in the course, we conclude that educators are seeking opportunities for professional development through online delivery. We have demonstrated that this course fulfills the need to help educators increase their science content knowledge and adopt an inquiry-based pedagogi-

cal approach to teaching science. This course could also be offered to PK-12 pre-service teachers.

The curriculum design and model of instruction of ENTO 810, including online delivery, is a viable pedagogical approach for integrating science content with science processes, and serves as a model of instruction for other life sciences-based courses that target educators and other professionals.

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