Moving from Hands-On to Inquiry-Based:

A Biology Course for Prospective Elementary Teachers

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To meet the needs of prospective elementary teachers, we offer a specialized biology course, “Hands-On Biology,” at the University of Nebraska-Lincoln (UNL). The original approach to the course, as indicated by its title, was oriented toward hands-on activities transferable to K-8 classrooms. Many teacher preparation institutions offer similar courses and using transferable activities is one of the most popular approaches (Michelsohn & Hawkins 1994). When the course was designed in 1994, the primary objectives were to improve prospective elementary teachers’ attitudes toward science and increase self-efficacy in science teaching. With the publication of the National Science Education Standards (National Research Council [NRC] 1996), we re-examined the original goals and design of the Hands-On Biology course. As science teacher educators, our work was guided by Professional Development Standard A, “Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry” (NRC 1996, p. 59). In the summer of 1997, we revised the course, focusing on aligning the course’s curriculum, instruction and assessment more closely with the Standards.

Format of the Hands-On Biology Course

From its initial offering, the Hands-On Biology course has been extremely popular with students majoring in elementary education. The course is a collaborative effort between the School of Biological Sciences and Teachers College, and is taught by a team of faculty and graduate students from both colleges. The Teachers College faculty who are involved with the Hands-On Biology course also teach sections of the Elementary Science Methods course. This collaboration allows instructors to make strong connections between the science content and pedagogy courses. Currently, the teaching team consists of an instructor from the Elementary Teacher Education Program and a graduate student in biology. Both individuals have experience teaching biology in grades 7-12. The teaching assistants are majoring in elementary education and are former students in the Hands-On Biology course.

The Hands-On Biology class meets twice a week, with two-hour and three-hour time blocks. The course enrollment is limited to 24 students. We assign students to learning teams of four students each. When possible, learning teams consist of freshmen as well as upperclassmen to facilitate informal peer mentoring within the Elementary Teacher Education Program. With experience, we have found that students prefer to remain on the same learning team for the entire semester. Students engage in a variety of long-term projects, which makes regrouping difficult. We have also found that semester-long learning teams foster stronger collaborative relationships within teams. The student-centered emphasis in the course has been maintained. Working within their learning teams, students spend the majority of class time engaged in inquiry-oriented investigations and projects.

Instruction

In moving from an activity-driven orientation to an inquiry approach, we examined instructional models
that support inquiry. In revising the course, our instructional strategies were primarily based on the 4-E Science Learning Cycle Model and Haury’s (1995) Circle of Inquiry.

4-E Science Learning Cycle Model

The 4-E Science Learning Cycle Model, as described in Teaching Science for All Children (Martin et al. 1997, pp. 303-311), consists of phases of exploration, explanation, expansion and evaluation. In the exploration phase, students interact with biological materials, making observations and asking questions. Using the flower lab as an example, students are initially asked to observe and sketch a flower. In the explanation phase, the instructors lead the students in a discussion to develop the biological concept. In the flower lab, we ask several students to reproduce their sketches on the whiteboard for the entire class to view. In a whole class discussion, we ask students to draw on their prior knowledge of flowers. With probing questions from the instructors, the students discuss floral structures and their related functions. Oftentimes, the discussions generate new questions that cause us to return to the biological material to make additional observations. We ask students to describe the pattern of symmetry that they observe in their particular flower. In the expansion phase, students return to the biological materials and apply the biological concept in a new way. In the flower lab, students are given a variety of flowers and are asked to compare floral structures and symmetry. Later we will draw on these comparisons when discussing plant classification. The fourth phase is evaluation, which is ongoing and occurs throughout the 4-E Learning Cycle. We informally assess our students’ understandings in each phase of instruction. Throughout the flower lab, students record their observations and questions in their journal. As homework, students use their journals to reflect on their conceptual understanding of the topics discussed in class.

Circle of Inquiry Model

Haury’s Circle of Inquiry Model was designed for use with elementary age children and provides an alternative to the linear, step-wise scientific method that many of our students had memorized but few had actually experienced in science courses. The Circle of Inquiry Model has four components: wondering, collecting data, studying data and making connections (see Figure 1). The model has no set entry point, but we tend to engage our students in inquiry by asking them to make observations of particular living material. We found that the Circle of Inquiry Model fosters students’ curiosity. Our students gained confidence in their ability to ask testable questions and to investigate those questions. The Circle of Inquiry Model represents science as an ongoing process of inquiry. For an example of curriculum designed according to the Circle of Inquiry Model, see Table 1.

During class, we are explicit about the use of these two instructional models: the 4-E Learning Cycle and the Circle of Inquiry. The NSES Professional Development Standard B focuses on knowledge of science teaching. “Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching” (NRC 1996, p. 62). As we use each instructional model, we share an overview of the model with our students. After instruction, we ask students to reflect on different class activities and to make connections to the instructional model. As a group, we also reflect on the fruitfulness of the model for science learning.

The Curriculum

As instructors, we reaffirmed our commitment to placing a high priority on modeling pedagogy and the use of materials appropriate for K-8 classrooms. In reviewing the curriculum, we reflected on the issue that former students often viewed the course as a science methods course rather than a science content course. In the past, science content appropriate for a K-8 science curriculum had driven the scope of the Hands-On Biology curriculum. We made the decision to increase the biology content in the course to support the development of scientifically literate adult learners.
Table 1.

Breadmaking 101.

Materials
- 2 small flasks
- 2 thermometers
- warm water
- 3 packages of dry yeast
- 3 small balloons
- 1 measuring cup
- granulated sugar
- measuring spoons

Collecting Data
Following the directions on the package of yeast, mix up the yeast, water and sugar in one of the flasks. Place a balloon over the top of the flask.
1) I predict …
2) After awhile, my group observed …

Wondering
3) My group wonders what would happen if we would …
4) Our group plan for testing our idea is to …
5) Our setup is …
6) Our plan for measuring our results is to …

Collecting More Data …
7) In our second experiment, we observed …

Studying Data …
8) In looking at our results, we think that …

Making Connections …
9) Prepare a summary of the group’s findings to share with the class.
10) If we were to continue experimenting with yeast, my group would like to …
11) What I learned about yeast …

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While revising the Hands-On Biology curriculum, we referred to the NSES Content Standards to guide our decision making in regard to the following questions:

- Does the Hands-On Biology course reflect the unifying concepts and processes of science as outlined by the NSES?
- Does the course curricula reflect the NSES inquiry content standards?
- How can extended inquiry projects be included to represent the nature of research in biology?
- Does the biology content reflect the Life Science Content Standards for grades K-4 and 5-8?

- Does the curriculum prepare students to be scientifically literate citizens?

We sought to develop a strong conceptual understanding of major themes in biology, while using inquiry-based instruction appropriate for K-8 classrooms. NSES calls for “less emphasis on covering many science topics … and more emphasis on studying a few fundamental science concepts” (NRC 1996, p. 113). Using this guideline, we selected four unit topics based on a review of the Life Science Content Standards for K-4 and 5-8. Using these content standards as a guideline, we wanted the Hands-On Biology course to continue to be relevant to the future needs of prospective elementary teachers. The Life Science Content Standards state:

As a result of activities in grades K-4, all students should develop understanding of:

- The characteristics of organisms
- Life cycles of organisms
- Organisms and environments (NRC 1996, p. 127)

As a result of their activities in grades 5-8, all students should develop understanding of:

- Structure and function in living systems
- Reproduction and heredity
- Regulation and heredity
- Populations and ecosystems
- Diversity and adaptations of organisms (NRC 1996, p. 155)

We selected plants as the starting point for the course, exploring the life cycle of a flowering plant, beginning and ending with seeds. To scaffold conceptual development, we chose to start at the level of the organism, moving toward macro levels of organization, reaching biomes toward the end of the third unit. Following the Plant and Animal Units, an Ecology Unit introduces members of the Monera and Fungi kingdoms. In the final unit, the focus moves to a micro level, studying cells and cellular processes (see Table 2). In a similar biology course at the University of Wyoming, Beiswenger, Stepans and McClurg (1998) report initially using a micro-to-macro approach in designing science courses for prospective elementary teachers, but reversing the sequence of topics in their course revisions.

We continue to incorporate examples of exemplary elementary science curricula, drawing on materials from AIMS, FOSS, GEMS, Project Aquatic, Project Learning Tree, Project Wild, and Agriculture
Table 2.
Revised Content Outline for Hands-On Biology.

A. Plants
1. Plant Project: Growing and Observing Wisconsin Fastplants®
2. Life Cycle of a Flowering Plant
3. Plant Structure and Function:
   a. Seeds
   b. Roots
   c. Stems
   d. Leaves
   e. Flowers
4. Specialized Stems: Trees
5. Flowering Plant Classification: Monocots & Dicots
6. Photosynthesis

B. Animals
1. Animal Project: Critter Care
2. General Characteristics of Animals
3. Major Animal Phyla Overview
4. Animal Behavior Studies
5. Animal Structure/Function
6. Life Cycles of Insects: butterflies and mealworms

C. Ecology & Decomposers
1. Ecology Project: Biome Boxes
2. Food Webs & Trophic Levels
3. Ecosystems
   a. Biotic
   b. Abiotic
      1) Water Cycle
      2) Carbon Cycle
4. Decomposers & Compost Piles
   a. Bacteria
   b. Fungi
5. Biomes

D. Cells: A Look Within
A. Cell Structure & Function
B. Cell Processes
   1. Cell Respiration
   2. Cellular Division
C. Human Genetics

The second major shift in course curricula occurred in response to the NSES “Inquiry as Content” Standard. We replaced many of the quick, easy-to-do activities with longer term inquiry projects. The Critter Care Project in the Animal Unit is an example of one of the three new inquiry projects.

The Critter Care Project is designed to engage students in extended inquiry. Each learning team selects an invertebrate to study for approximately four weeks. Students select from a list of invertebrates that are available locally. Mealworms, hissing cockroaches, crickets, and crawfish are popular choices. Working in their learning teams, students research the food and habitat requirements of their selected invertebrate, and then design suitable habitats before obtaining the organisms. For the first two weeks, students observe the organisms and record their observations in their journal. From their observations, students generate testable questions relating to the organism’s behavior. The students design and present an initial plan for investigating their testable questions. After receiving feedback from other learning teams and the instructors, the students revise their plans and carry out the investigations. We encourage students to observe each learning team’s invertebrate and to ask questions relating to care, feeding, and behavior. In this way, students will be knowledgeable and comfortable using a variety of invertebrates in their future classrooms. At the end of the project, we hold a symposium and each team shares its findings with the class. As part of this inquiry project, we build in connections to K-8 classrooms. Students develop lesson plans for engaging children in inquiry-oriented activities with their selected invertebrate. Students find children’s books that highlight their selected invertebrate. As part of the symposium, each learning team shares its lesson plans and reading list.

At the suggestion of our teaching assistant, we incorporated children’s literature throughout the semester. Each week, a children’s literature book that connects to the week’s science content is read aloud and discussed in class. Cynthia Mahler, a former student with a strong interest in children’s literature and a familiarity with the course, selected the children’s books, highlighting a variety of authors. This very short portion of the week’s class time became extremely popular with the students. After the first semester of incorporating children’s literature, we shifted the responsibility for the literature connection to our students. Pairs of students sign up to share selections of children’s literature on a weekly basis. The students receive our initial recommended list of children’s books but are also encouraged to make additions to this resource list.
Assessment

The NSES Professional Development Standard C states, "Professional development activities must provide opportunities for teachers to learn and use various tools and techniques for self-reflection and collegial reflection, such as peer coaching, portfolios, and journals" (NRC 1996, p. 68). From the inception of the course, student journals have been the primary assessment tool. Because we viewed the student journals as a powerful tool for reflection, we chose to continue student journal writing.

In planning student assessment, we used the following NSES guidelines for "changing emphases" in assessment. The instructors sought to place more emphasis on:

- Assessing what is most highly valued
- Assessing rich, well-structured knowledge
- Assessing scientific understanding and knowledge
- Assessing to learn what students do understand
- Students engaged in ongoing assessment of their work and that of others. (NRC 1996, p. 100)

Student journals and group projects continue to be our primary method of formal student assessment. Based on our past experiences with student journals, we adopted a more structured approach to journal writing. Student journals became a record of all class activities, discussions, assignments and reflections. Student journals were used to meet the following goals:

1. Create a future resource document of class activities.
2. Provide a means of processing class activities and reflecting on individual learning.
3. Make connections to elementary science teaching.

The instructors read student journals on a weekly basis as a means of ongoing assessment. (See Table 3 for the revised journal format.)

In addition to restructuring the journal format, we incorporated more instances of eliciting students' prior knowledge on a specific topic. Before introducing a new unit or topic, students are asked to write what they already know about the topic in their journals. For example in the Plant Unit, students were asked to respond to the following prompt: "What I remember about photosynthesis is . . ." Students then share their journal entry with members of their learning team as a means of initiating a class discussion. We also arrange times during the semester when students exchange journals with each other, giving feedback.

Research Findings

Two research studies have focused on the Hands-On Biology course. Crowther and Bonnstetter (1997),

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<th>Table 3.</th>
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<td><strong>Journal Assignment Format for Hands-On Biology.</strong></td>
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<td>In your weekly journal entry, keep a detailed, organized record of the week's activities and class discussions. For each investigation, you need to include the following information: the purpose, description of materials and procedures, and a summary of what you personally learned from the investigation.</td>
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<td>At the end of each weekly entry, include reflective responses to three of the four questions listed below. Question #1 is required each week.</td>
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<td><strong>Journal Questions</strong></td>
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<tr>
<td>1. Summarize the &quot;Big Ideas in Biology&quot; from this week's classes. This may be accomplished through a written summary, a drawing, designing an original activity for a K-8 classroom, creative writing, etc.</td>
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<td>2. Select two activities/investigations from class and describe how you might use these in an elementary school setting. Match each to the National Science Education Standards for grades K-4 or 5-8. Be sure to include modifications and/or extensions for your selected activities/investigations.</td>
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<td>3. Using additional resources, explore in greater detail a biology topic discussed in class. Write a summary of your expanded understanding of the topic and any new questions that you have. Be sure to include references.</td>
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<td>4. Assess your own learning of the biological concepts explored in class this week. What is your past experience with a particular concept? How did the class activities help you think about the concept in a different way? How does the biology concept connect to your life? What additional questions do you have about the topic?</td>
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using a multiple case study approach, generated a substantive theory for stages or hurdles that the prospective elementary teachers experience as learners in the Hands-On Biology course. They found that the students initially express reservations and hesitation, then move into an enjoyment stage, followed by an intrinsic shift in which the students focus on their own learning. The fourth stage is a rapid building of self-confidence and self-efficacy, leading to the final stage of empowerment.

In their evaluation of the Hands-On Biology course, Reisetter, Bruning and Veommett (1998) found: “students underwent substantial positive changes in their confidence in themselves as science learners, their beliefs in the utility of science, and their liking of science. Similarly, large changes were noted in their self-efficacy as teachers of science and in their ability to perform as learners and colleagues.”

As instructors, we have received positive feedback on course evaluations completed by students. The Hands-On Biology course continues to be popular among prospective elementary teachers at UNL. As a result of prospective teachers’ enrollment in the Hands-On Biology course, field supervisors report observing an increase in biology lessons taught by elementary education students in their field placement schools (R. Egbert, personal communication, 1997).

Conclusion

The Hands-On Biology course is a collaborative effort between the School of Biological Sciences and Teachers College. The National Science Education Standards were used as a guideline in revising the course with the primary goal of shifting the emphasis away from an activity-driven orientation to an inquiry orientation. To accomplish this goal, we examined and revised the curriculum, instruction and assessments in the course to more closely align with the Standards.

After the course revision, there are new issues that surround this science content course for prospective elementary teachers. The Hands-On Biology course, initially supported through grants from the Howard Hughes Medical Institute, needs to be institutionalized at our university. Work is currently underway to institutionalize Hands-On Biology within the School of Biological Sciences. Requiring the Hands-On Biology course as part of the

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Elementary Teacher Education Program would accelerate the institutionalization process.

Using graduate students with K-12 teaching experience as instructors has given the course credibility among the students. However, graduate students typically only teach the course for a few semesters before leaving the university. Due to the unique nature of the course, a transition period between instructors is essential. Using a model that includes tenured faculty and graduate students may offer a solution to the issues of institutionalization and continuity between instructors. Elementary science specialists in the local school district, as well as secondary biology teachers, might be recruited to be part of the instructional team. At times, the Hands-On Biology course has been offered in the evening, which would make it possible to hire local teachers to be part of the instructional team.

The Hands-On Biology course is a collaborative inter-college effort to meet the needs and goals of prospective elementary teachers. Through the revision of this course, we hope to better prepare our students to meet the vision of reform-based science teaching.

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**References**


