Applying Plant Identification Skills

To Actively Learn the Scientific Method

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Active learning approaches are being promoted in efforts to improve the quality of science education in the United States (George et al., 1996; Moore et al., 1997). Students who actively participate in their learning retain information better (Christian & Fisher, 1999) and develop more independent learning strategies (Goodwin et al., 1991) than their counterparts who experience primarily lecture style instruction. Active learning provides multiple teaching and learning strategies that can be applied in the science classroom (Chiappetta, 1997). Educators are therefore using active learning techniques in various fields of science (e.g., Anthony et al., 1998; Johnson, 1998; Stadler, 1998).

The scientific method provides an excellent framework for actively involving students in their own learning (Sterner, 1998) and scientific research has been promoted as a teaching model (Moore et al., 1997). Klapper (1995) comments that science as a procedure is imperfect since people who bring with themselves biases and shortcomings perfom it. He also points out that teaching the scientific method is misleading as it is often not followed explicitly in scientific endeavors. Despite sociological difficulties in the real life application of the scientific method and therefore its transfer to the classroom, science teachers are using the traditional scientific method effectively to promote active learning in their classrooms (Favero, 1998; Williamson & Smoak, 1999).

The objective of this paper is to describe a course in which I incorporated the scientific method as a framework for active learning in the discipline of systematic botany. I used the scientific method, despite its pragmatic difficulties, because it forms the basis of scientific practice and is therefore foundationally important to students of science. I used active learning methods to promote ownership, enthusiastic interest, and long-term learning habits in the students.

Course Philosophy

The State University of New York College of Environmental Science and Forestry (ESF) bases its curriculum on a field-oriented perspective on learning. Many of its graduates enter fields of environmental analysis and consulting along with other applied aspects of science and engineering. I sought to build on the experience of an existing course (Systematic Botany) where students learn how to use a technical key for the
identification of plants, are introduced to important flowering plant families, and study the discipline of angiosperm taxonomy. I designed the new elective course, titled Field Applications of Systematic Botany (FASB), to provide an applied field experience that was lacking in the parent course. The objective was to provide an opportunity for students to learn about the scientific method and the way that science is done through an active learning experience, building on the scientific knowledge provided in Systematic Botany.

My approach was to use the instructional research and development framework (Spuches & Coufal, 2000) to promote the use of active learning and scientific application in both systematic (for course development) and systemic (for curriculum development) ways. Instructional research and development is based on the principles of analyzing the current condition of a course, designing and developing alterations, running a trial, evaluating that trial, defining the new course condition, and beginning again from analyzing the new condition of the course (Figure 1).

Students in FASB use the tool skill of flowering plant identification to help themselves make ecological observations about plant species, plants, and plant communities. They then develop self-generated questions about those observations and actively use the scientific method to propose studies to test the hypotheses generated from the initial questions. Therefore, students engage in the scientific process based on their own observations and questions. While active learning is being used in science education already (Chiapetta, 1997), I have added an element of ownership for the students by requiring that they develop their own questions, hypotheses, and proposals. Ultimately, because science is a corporate process and depends on proficient communication, students engage in peer critique of their hypotheses and proposals and orally present their proposals in the format of a scientific meeting (Figure 2).

Course Specifics

I implemented this course in the fall semester of 2000. The first four weeks were spent visiting field locations of various ecosystem types and assisting students with identifying flowering plant species in a self-directed format using Newcomb's Wildflower Guide (Newcomb, 1977). I encouraged students to identify as many species as possible in a non-destructive manner. As students identified plants, I directed them to make qualitative observations regarding plant health, phenological stage, and associated species, as well as ecological characteristics and habitat. Hence, the tools of systematic botany as exemplified by plant identification were present in the formative steps of the students' projects.

The second stage of the course involved the development of questions related to the observations made in the field. Based on their questions and observations, students formed hypotheses to address their questions. The three students in the class developed the following hypotheses: disturbance increases herbaceous plant species diversity, the presence of non-native plant species decreases the abundance of native old-field beetle species, and shade limits height growth in goldenrods differentially by species. Clearly, plant identification and the appreciation of plants as parts of ecosystems are explicit in the students' hypotheses. The hypotheses were scientific; that is they were testable, refutable, and could explain the observation. Additionally they provided a basis to make predictions regarding the phenomenon of interest. The predictions formed the theoretical framework of the student's research proposals. To incorporate peer review and critique, the students spent a class period reading each other's potential hypotheses and helping to decide which would lead to the strongest proposal.

Student research proposals were separated into three parts. First, a background and introductory section was included to review pertinent literature and define the importance of the question. Students read a recent scientific journal article and we critiqued the paper as a discussion to help them understand...
the format and nature of scientific articles. I introduced students, via interactive lecture format, to computer databases available at the ESF library where they could perform searches to find primary literature on which to base their introductions and to learn more about their chosen topic. In the methods section, students described in detail the quantitative approach they would take to test the predictions of their hypotheses. These methods needed to be thorough and repeatable as required for an actual scientific paper. Proposed methods included transect and systematic plot sampling for plants, malaise traps for sampling beetles, and a randomized complete block experimental design for a greenhouse setting. I required students to include statistical hypotheses to lead them to appropriate analyses of the data. I spent a class period lecturing about widely used statistical tests to help students frame their experiments and understand how the study would actually test the prediction of their hypothesis. This emphasis helped students to distinguish the differing format and utility of scientific and statistical hypotheses. Students proposed statistical methods including regression analysis and analysis of variance. Lastly, students included a section of results to describe verbally and graphically the predicted results of their experiments. Students explained how these results would be important to the topic and their relevance to society. Once rough drafts of their proposals were written, a class period was devoted to peer discussion and review of the proposals. I encouraged students to be constructive and helpful with their questions and comments to promote good habits in these future scientists.

I used the last class period for students to orally present their final proposals. The format of the classroom was that of a scientific meeting place where students had 10 minutes to present their proposal and then responded to questions from their peers and the instructor regarding any aspect of the work. Each student completed an evaluation form where they commented on the most and least effective parts of each presentation and provided advice on how to improve each other’s presentations.

The students did not carry out their studies within the class, as such efforts would have gone beyond logistic and economic bounds (the course was worth one credit). A future development of the course would be to garner funds to permit students to perform their studies and increase the academic investment to at least three credits. Such a change may also require the course to run over two semesters or include a summer component. One student did, however, plan to implement her proposed research as part of a summer internship that would lead to a senior project.

Course Evaluations

Students completed evaluation forms to judge the success of the course from their perspective. They approved of the active learning techniques and felt that they had developed a good understanding of the foundational aspects of the process of science. There was general agreement that the framework for developing hypotheses and proposals would be immediately useful to them in their careers as critical thinkers and scientists. One identified shortcoming was that by the fall semester there were too few plants still in flower that did not belong to the Aster family. This is perhaps an unavoidable drawback of the timing of academic semesters in the northeastern United States. Students also suggested that using more formal sampling techniques during the field trips would help them in the development of the methods sections of their proposals and also help them with hypothesis generation.

As the instructor, I felt that overall the course went quite well for a pilot class. The students’ hypotheses, proposals, and peer-review skills improved considerably during the term. The critical reasoning and scientific character of the students’ proposals were of high quality by the time of final drafts and oral presentations. Student ownership of their hypotheses helped to engender a sense of responsibility and commitment. Some alterations would make the course better in the future. First, although a consistent example (yellow trout lily growing largest near tree bases) was used to demonstrate observations, hypothesis generation, and methods
articulation, it would be even more useful to fully develop this example to include a sample proposal and oral presentation based on the example. A single example carried through the entire class would be more helpful than the unrelated examples given for proposals and oral presentations. Second, I agree with the students that some examples of sampling methods would be helpful in the beginning of the course. Third, because some students felt they needed more time to develop the first draft of their proposal, I will ask them to first develop an outline to help them formulate ideas and their approach before they begin to write the proposal. Last, long term planning for the course may permit the expansion of time and monetary investment mentioned previously (see Course Specifics).

FASB worked well with a small class of three students. We met once per week for up to three hours at a time. More time was spent per class period during field trips and less during discussions and topic introductions. Larger classes could make use of this course design provided more meetings per week. A class of 20 to 30 students could meet twice per week for instruction and discussion and once per week for three hours early in the semester for field trips and again later in the semester to provide enough time for student presentations. These larger classes could easily be separated into groups of three to five students for discussion groups to make the peer review and critique more personal and helpful than a full class discussion might be. Such a class size would also provide opportunity to compare learning between small group and full class discussions. Perhaps both sizes would be useful in different ways to assist with student learning. A likely limit to class size for this course is 40 students. Larger classes would become logistically unmanageable for the detailed and active interactions and presentations requisite for this teaching and learning approach.

I offered this course to upper level undergraduates but it could easily be adapted for high school students given the availability of simple dichotomous keys for plants. The course could be run as a long-term lab with a goal of proposal development, or even experimental completion, by the end of the academic year. Regardless of the setting, the principles of active learning and student ownership of their ideas and projects are the keys to success for students in this course.

**Conclusion**

I sought to develop an active learning approach to the use of the scientific method as applied to systematic botany and plant ecology. This course guided students through making observations, asking questions, forming hypotheses, making predictions, designing experiments to test their predictions, and writing research proposals. Critical steps included peer review and critique.
to promote constructive criticism and group interaction revolving around the process of science. Ultimately, students presented their proposals orally in the format of a scientific meeting to complete the process of communication in scientific endeavors. Students performed well with obvious improvement and appreciated the course, seeing a direct applicability of the skills they developed.

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References


