Ecological controversy: analysis to synthesis

Kathy S Williams[1], Diane Ebert-May[2], Douglas Luckie[2], and Janet Hodder[3]

The article by John Banks (see pp 537–545) in this issue of *Frontiers* outlines innovative programs worldwide that integrate the seemingly opposed goals of agriculture and conservation biology to produce mutually beneficial outcomes. This ecological conflict and subsequent movement towards integration provides an opportunity for students to actively learn science by structuring arguments for both sides of an issue, then synthesizing and integrating the best evidence and reasoning into a position statement. The intellectual skill of challenging the thinking of others by developing arguments is highly desirable in undergraduates (Conley 2003). By practicing critical analysis of arguments, students can move toward higher levels of reasoning (Toulmin 1958).

A common concern of instructors is "giving up" lecture time to implement student-centered activities during class. In part, this is based on the poorly supported assumption that students learn best through lecture (Posner *et al.* 1982; Bransford *et al.* 1999). However, research shows that students construct understanding better by interacting and processing information in small groups (Johnson *et al.* 1996; Springer *et al.* 1999). Nevertheless, the challenges of implementing small group experiences in large classes are not trivial, nor is ensuring student accountability for participation. Here we use a structured controversy based on Banks' paper to help students understand a complex ecological problem, and provide instructors with multiple forms of assessment to determine if the controversy "works" (ie helps students achieve the goals).

Goals for students

- Write a group position statement that synthesizes arguments and evaluates evidence about whether or not integrating agriculture and conservation biology effectively contribute to sustainable ecosystems.
- Integrate concepts of habitat diversity, insect population dynamics, biological control, pesticides, genetically modified (GM) organisms, and spatial scale into the argument.
- Assess the complexity of ecosystem management and difficulties in evaluating alternative approaches.
- Improve capacity to work as a member of a productive, collaborative group.

Goals for faculty

- Implement a structured controversy as a learning strategy in a large class.
- Evaluate the benefits of using structured controversy by (a) asking formative questions to determine students' assumptions and attitudes, and (b) analyzing their abilities to understand and synthesize information on the topic.

Instructional design – structured controversy

In a large (or small) class setting, the instructor engages students with a relevant current issue, then guides groups of four students, subdivided into pairs, through the process of controversy and resolution. In this example, all groups address the following issue: Both agriculture and conservation biology stakeholders are concerned with managing natural resources, despite conflicting goals of food production versus maintenance of biological diversity.

Assumption: Agricultural productivity is essential, while preserving natural sustainable systems is also seen as beneficial.

The class is challenged to weigh three perspectives proposed in this paper:

(a) Chemical versus biological controls of agricultural pests
(b) Managing planting for diverse versus simple (monoculture crop) planting systems
(c) Use of GM versus horticultural cultivars of crops

Students are responsible for reading the paper and understanding all three perspectives. Each group is assigned one perspective for further study (either a, b, or c). Both pairs of students within teams research both sides of their perspective using the Banks paper and additional materials (eg Zycherman and Taylor 2004 provide resources for a GM plant controversy). Each pair prepares a one-page persuasive argument that advocates and refutes both sides of their perspective, and concludes with a position statement for one side, derived from the most convincing ecological evidence. Consequently, students synthesize evidence and construct arguments, and then, working collaboratively, elucidate a knowledgeable position about the conflict between food production and maintenance of biological diversity.

In class, groups reconvene and are assigned randomly to argue one side of their position, and discuss the evidence supporting that position. Each group prepares a 2-minute oral presentation and selects a speaker to present it to the class. The structured controversy begins and the instructor selects groups to present well-supported arguments about the issues to their peers. Students are encouraged to ask questions and take notes during the discussion.

Assessment

The questions in Panel 1 are formative assessments, designed to inform the instructor and class about student positions before, during, and after the controversy exercise. Instructors collect students' responses to the questions using personal response systems ("clickers") if

[1]*San Diego State University,* [2]*Michigan State University,* [3]*University of Oregon*

available, or bubble sheets.

Next, have students imagine they are members of a panel of ecologists reviewing three proposals from companies who want to develop large-scale agricultural systems in previously uncultivated lands along a river in central Mexico, or in a local region, if appropriate. The three proposals differ only in their methods of insect pest control, use of GM plants, and planting patterns. Rank the following three proposals based on which will preserve and sustain local ecosystem functions most to least:

(a) This agricultural plan uses biological controls, GMOs, and diverse planting patterns.
(b) This agricultural plan uses chemical controls, GMOs, and diverse/heterogeneous planting patterns.
(c) This agricultural plan uses biological controls, selective breeding, and simple/homogeneous planting patterns.

Alternatively, these examples could be replaced by combinations generated by students. Either approach would address the goal of helping students understand the complexity of ecosystem management and difficulties in evaluating alternative approaches.

Finally, students demonstrate their ability to synthesize the arguments and evaluate positions by explaining *why* they think their first choice is better than the second and third, in terms of habitat diversity, insect population dynamics, biological control, pesticides, GM organisms, and spatial scale. A rubric distributed before class will guide student responses and assist instructors with evaluation (see Web Panel 2 for an example).

Ask students to close by recommending three features of the natural systems at risk that should be monitored to measure success if their first choice was implemented. The effectiveness of group interactions can be assessed by asking students to evaluate what they gained from working collaboratively on the controversy.

Analysis and discussion

Although most instructors consider it important to assess the effectiveness of active-learning instructional approaches, it is not easy to design assessments and analyze data that test their efficacy. The questions to ask about this activity include:

- Did active learning enhance students' understanding of the ecological concepts embedded in the controversy?
- Did students' thinking change during the course of the activity?
- How do students respond to subsequent exam questions related to the learning goals of the activity?
- How well did the cooperative groups function?

To answer these questions, two types of assessment are used: (1) self-report data about students' thinking about issues before, during, and after the activity, and students' assessment of their group interactions, and (2) direct data from students' analysis and synthesis of issues and application to a real world scenario. Critical evaluation of the data will enable instructors to explain not only *what* students know, but also *how* they learn. Ultimately, these results will inform future class sessions and generate additional questions and research about the effect of active learning on student understanding.

Panel 1. Formative assessments

Instructors assess students three times (before homework, beginning of class, after class controversy), by asking them to respond to each of the statements below with: (5) strongly agree, (4) agree, (3) neutral, (2) disagree, (1) strongly disagree.

1a. Use of chemical pesticides and fertilizers is the best way to control agricultural pests and increase productivity.
1b. Use of biological controls on pests maintains biodiversity of native pollinators and parasites and decreases productivity.

2a. Large-scale monocultures (eg corn or wheat) lead to the greatest agricultural productivity.
2b. Diversified planting practices (mixed crops) help preserve natural ecosystems.

3a. Planting GM species of crops is an effective way to reduce pest losses and increase crop yields.
3b. Planting commonly used horticultural varieties will have little effect on native insect species but will decrease crop yields.

Then ask students, as informed biologists, to decide which perspective from each pair above (1, 2, and 3) they would recommend for commercial agriculture to preserve the functioning of natural systems. Support each choice with one ecological reason.

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References

Bransford JD, Brown AL, and Cocking RR. 1999. How people learn: brain, mind, experience, and school. Washington DC: National Academy Press.

Conley D. 2003. Understanding university success. Report: Association of American Universities and Pew Charitable Trusts. Eugene, OR: Center for Educational Policy Research.

Johnson DW, Johnson R, and Smith K. 1996. Academic controversy: enriching college instruction through intellectual conflict. ASHE-ERIC Higher Education Report 25(3). Washington DC.

Posner GJ, Strike KA, Hewson PW, and Gertzog WA. 1982. Accommodation of a scientific conception: toward a theory of conceptual change. *Sci Educ* **66**: 211–27.

Springer L, Stanne ME, and Donovan S. 1999. Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: a meta-analysis. *Rev Educ Res* **69**: 21–51.

Toulmin S. 1958. The uses of argument. Cambridge, UK: Cambridge University Press.

Zycherman D and Taylor J. 2004. What are the ecological impacts of plant biotechnology? Teaching Issues and Experiments in Ecology, Volume 2: Issues Figure Set #1 [online]. http://tiee.ecoed.net/vol/v2/issues/figure_sets/biotech/abstract.html. Viewed 8 November 2004.