Effects of a Problem-Based Learning Approach on Attitude Change and Science and Policy Content Knowledge

Introduction

Two primary objectives of environmental education are to inform and influence opinion on the impact of human activities on the environment (Orr 1994; Bednar 2003). One methodology is the open-ended, problem-based learning approach, in which students are assigned a real-world environmental problem to critically evaluate. The problem is open ended in the sense that there is no universally accepted correct answer to discover. To successfully complete their evaluation, students must learn enough about the topic to read and understand the relevant research and apply this knowledge base to weigh conflicting expert opinions about the problem (Allen et al. 1996; Campa et al. 1999).

Problem-based learning is becoming a popular pedagogical approach among advocates of reform in science education because it is purported to be more effective at motivating students to learn independently. When students learn independently, they discover the relevance of the content to real-world applications (D'Avanzo 2003*a*, 2003*b*; Hmelo-Silver 2004). Although this claim seems reasonable, there are little quantitative data to support the effectiveness of problem-based learning in improving content knowledge and changing attitudes related to the environment and conservation (Tomsen 2002; McMillan 2003; Hmelo-Silver 2004).

We were recruited to teach a general-studies science course required as a component of the curriculum of all third-year students enrolled in our university's honors program, a selective program for academically gifted students. We chose to focus our course on the scientific and sociopolitical issues associated with habitat conservation via large-scale reserve networks. We designed a problem-based course that examined one complex and controversial regional environmental issue: a proposed transnational biological corridor between two large protected areas in the United States and Canada. It was our hope that the experience of participating in this course would result in students who understand more of the basic principles of conservation science and environmental management and have a more favorable opinion of efforts to preserve biodiversity through regulation of land use. Moreover, we hoped that these knowledge and attitude changes would persist long after the conclusion of the course.

To test whether our objectives were met, we administered a questionnaire to students before the start of the course, at the end of the course, and 16 months after the end of the course. This questionnaire included factual content and opinion questions related to conservation science and environmental management. We also administered the questionnaire to a control group of demographically similar students who were not in the course. We sought to determine whether an open-ended problem-based learning course results in long-term improvement in factual content knowledge and changes in attitudes about conservation science and environmental management.

The Problem: Justifiability and Feasibility of the Adirondack to Algonquin Biological Corridor Initiative

The Adirondack to Algonquin Corridor (A2A) initiative is a policy proposal aimed at delineating a biological corridor along a 275-km zone from the northwest corner of Adirondack State Park in New York State through the St. Lawrence River Valley, crossing the St. Lawrence River in the Thousand Islands region, and then running along the Frontenac Axis area of eastern Ontario to Algonquin Provincial Park. The proposed corridor is approximately 8600 km^2 (Lee et al. 2000; Quinby et al. 2000). The objectives are to preserve biological connectivity and promote environmentally sensitive sustainable economic development via transnational ecotourism. The principal advocates have been the Canadian Parks

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and Wilderness Society, the Wildlands Project, and local environmental advocacy groups in Ontario. Methods proposed for preserving this corridor include incentives to private landowners for providing appropriate stewardship, imposition of legal restrictions on usage of private lands, and expansion of public lands. The A2A biological corridor initiative is one of several proposals to increase connectivity among forest lands in the region, including a corridor connecting Algonquin Park to the Temagami wilderness region of Ontario, corridors connecting the "northern forest region" from Adirondack Park through northern New England to the forests of New Brunswick, and corridors connecting Adirondack Park to the Appalachian Mountain chain (Fleming 2001). The A2A corridor was conceived as one link in an envisioned network of regional reserves across North America (Soulé & Terborgh 1999).

The proposed A2A corridor region is an area of low population density and high forest cover, except for the area adjacent to the St. Lawrence River. Road density is low, but it is bisected by one major divided highway (the Trans-Canada Highway, Ontario Highway 401). On either side of the corridor region are areas of high population density and intensive human land use (Jenkins & Keal 2004). Adirondack Park is the largest protected forest area in northeastern North America (23,200 km^2), and Algonquin Park is the sixth largest in the region (7,630 km^2; Gurd et al. 2001). The two parks were established for similar reasons in the late nineteenth century, and both are managed as multiuse areas that include a patchwork of absolute preserves and zones of active resource exploitation (Terrie 1994; Ontario Ministry of Natural Resources 1998; Pasquarello 1998). Both are major regional tourist draws. The two parks are ecologically similar and are classified as boreal forest–northern deciduous forest transition (Ricketts et al. 1999). There is one confirmed instance of a moose (*Alces alces*) traveling from Adirondack Park to Algonquin Park, probably through the region of the proposed corridor.

Poverty is high within the A2A region, and residents have a complicated, often adversarial, relationship with governmental agencies (Terrie 1997; Pasquarello 1998). Currently there are heated public debates in the region over regulations on private land use, funding and staffing of agencies involved in environmental conservation, jurisdiction of competing governmental agencies, motorized-vehicle policy (especially snow machines and all-terrain vehicles) on trails and roads, proposed construction of a new interstate highway across northern New York, expansion of shipping in the St. Lawrence River, and policies concerning wolves (e.g., whether to reintroduce wolves in Adirondack Park and whether to regulate killing of wolves in the vicinity of Algonquin Park).

Students in our course were asked to research the following questions and report their answers in the form of a policy white paper: (1) Is the A2A corridor proposal biologically justifiable? In other words, would a biological corridor substantially improve connectivity between Algonquin and Adirondack parks such that the ecological integrity of each is more assured? Or would resources be more productively allocated to other conservation goals such as better stewardship of each park? (2) Is the A2A corridor initiative socially, politically, and economically feasible? In other words, is there potentially enough support among stakeholders for an A2A corridor initiative to be established and can it be economically sustainable?

Curriculum and Class Composition

Course Design

We created the course. One of us specializes in ecology and conservation biology (T.L.) and the other (R.W.) specializes in rural sociology and agriculture and environmental policy. This semester-long (15 weeks) course in fall 2001 consisted of three weekly components: a faculty content lecture, a class discussion based on assigned readings, and a guest speaker. Content topics included the environmental history of the A2A region, conservation biology (including single-species management, maintaining biological community integrity, and the theory and practice of reserve design), environmental ethics, environmental economics, agricultural production and its environmental impacts, the politics of ecosystem management, theory and practice of land-use regulation, and ecotourism. Readings consisted of chapters from three assigned texts (Noss & Cooperrider 1994; Cortner & Moote 1999; Bennett 2000) and a collection of readings that included white papers, review articles, and research papers. Students were also provided with a course Web page that included a comprehensive collection of links to organizations concerned with the A2A corridor region and its two anchor parks. Guest speakers were recruited from nongovernmental agencies (e.g., the Canadian Parks and Wilderness Society) and government agencies (e.g., the U.S. Fish and Wildlife Service) that are parties in deliberations over the A2A corridor initiative, and academic researchers with expertise in an area relevant to the development of the A2A corridor. Besides making a presentation to the class, each guest speaker was interviewed by a small group of students, who then wrote a transcript of the interview and provided it to other class members. To facilitate discussion, the course was taught in two sections. Although one of us took the lead role on each content module, we were both present at most of the class meetings. We tried to maintain a neutral stance toward the questions of whether the A2A corridor is justifiable and feasible (as indeed we were), but visiting speakers were encouraged to provide their own opinions on these questions. (Full details can be found in the posted course syllabus available from http://www.clarkson.edu/~tlangen/A2A/A2A%20links.htm.)

Students were required to write a weekly two-page reflective essay on what they had learned from the past week's readings, class discussions, and class lectures, with an emphasis on how these contributed to the students' evaluation of the A2A corridor policy initiative. Students were provided feedback from the instructors on the content and clarity of their essays. The principal assignment to the students, however, was to draft a white paper addressing the questions of whether the A2A corridor policy initiative is scientifically justifiable and socially feasible, based on the material presented in the course and outside research. The intended audience of the white paper was policy makers and other stakeholders within the A2A region. Students were provided actual white papers as models, and we gave some general guidelines on what a white paper should include. Students worked in teams of four or five members (nine teams total); students were randomly assigned to teams at the beginning of the semester. We intentionally used a cooperative (team-based) learning approach to emulate how white papers are generally developed and because cooperative learning is particularly appropriate for problem-based learning courses (Herreid 1998; Campa et al. 1999).

Students' final course grades were primarily (75%) based on the quality and clarity of the white paper their group had drafted. Students within a group anonymously evaluated the proportional contribution of each member of the group to the final product. Students who were judged by the consensus of group members to have provided less than their expected contributions to the group effort had their grade proportionally reduced, and those who were judged to have done more than expected were provided a proportionate bonus. The remainder of each student's grade was based on the quality of the weekly reflective essays (15% of grade) and discussion participation (10% of grade). There were no graded quizzes or exams in the course. Students were not directed to "learn" any specific content, and their course grade was not determined based on whether they could accurately answer questions on the content covered in the course.

Characteristics of Students

Clarkson University is a private, small (under 3000 undergraduates), second-tier national university (per *US News and World Report* rankings) that emphasizes programs in engineering, science, and business. Clarkson is situated 13 km from the northern border of the Adirondack Park and lies within or near the proposed biological corridor region (advocates differ on specifics of the corridor location). The 38 students that participated in the course were all members of the Clarkson University Honors Program, a selective program composed of students with exceptionally high standardized test scores (mean SAT score = 1400) and other indicators of potential high academic achievement. Students in the Clarkson Honors Program are obligated to take a series of core courses from their freshman through senior years of college, and a group of honors students progresses through these courses as a cohort. In 2001 third-year (junior-level) students in the honors program were required to take our course and had no choice in the course subject matter.

Most students in our course were engineering discipline (48%), engineering management (19%), or chemistry (13%) majors. The remaining students were biology, technical communications, mathematics, or business majors. None of the students had a major or concentration in environmental science, environmental engineering, or environmental policy. Only 6% claimed to be a member of an environmental organization. The mean (±SD) cumulative grade-point average of students enrolled in the class was 3.7 ± 0.24, which was higher and probably much less variable than the general Clarkson University student body (mean GPA = 3.0). Although the students in our class were motivated to attain high academic achievement, we perceived that the students considered our course a lower priority than those taken concurrently in their major field of study. Sixty-eight percent of the students enrolled in the course were men, and 81% were 20 years of age (range 19–21). All of these students had previously completed at least one course that applied a cooperative-learning, problem-based learning approach.

Many of the students (23%) originated from one of the 12 counties that lie partially or wholly within Adirondack Park. Most students (77%) originated from New York State; the remainder were either from the northeastern United States or international students. Most students (71%) recalled having visited Adirondack Park at some time previous to taking the class, but fewer students (13%) had visited Algonquin Park.

Students' Conclusions and Recommendations Concerning the A2A Corridor

During the course, students' opinions about the justification and feasibility of the A2A corridor fluctuated greatly from week to week depending on the week's readings, content lecture, guest speaker, and independent research. These fluctuations were indicated in their weekly written reflections and participation in discussions. There was a tendency in the written reflections and discussions for students to argue extreme positions, and one of our tasks as instructors was to challenge the students to consider alternative viewpoints and develop more nuanced perspectives.

Among the nine white papers prepared by the student groups at the end of the semester, however, there was a remarkable consensus that the A2A corridor policy initiative is justified from a conservation science perspective and feasible from a sociopolitical standpoint. Regarding the scientific justification of the A2A initiative, eight groups judged it justifiable, one group was uncertain, and no group judged it unjustified. For the question of political, social, and economic feasibility of the proposal, seven groups judged it feasible, one group was uncertain, and one group judged it unjustified.

The actual emphasis varied among groups: some stressed general theoretical concepts in conservation science and ecosystem management and others focused on specific issues pertaining to the A2A corridor initiative. In their white papers the groups made several specific recommendations regarding how to best plan and implement the A2A initiative:

- Conduct research on actual animal movements through the A2A landscape to understand regional landscape connectivity.
- Carefully plan future development (e.g., road network expansion, all-winter navigation on the St. Lawrence River) to avoid creating permanent obstacles to animal movement.
- Support community-based advocacy and policy making in the A2A region (bottom-up rather than top-down decision making).
- Minimize expansion of publicly owned land and promote and support good stewardship of privately owned land.
- Provide rewards to farmers who maintain environmentally sound farm practices, support small family farms, and discourage spread of concentrated animal-feeding operations.
- Create a market for agricultural and other products that are produced in an environmentally sustainable fashion in the corridor region (e.g., an "A2A certified green" label).
- Promote ecotourism via A2A motorized vehicle, bicycle, hiking trails, and other regional draws and promote A2A as a distinct region worthy of regional and continental tourist interest.
- Provide tax incentives or direct payments for permanent land easements on private land.

Assessment of Student Content Knowledge and Attitudes

Methodology

To quantitatively assess whether the experience of our problem-based learning course improved content knowledge and changed attitudes about conservation and environmental management, we administered a written questionnaire immediately before the start of the course (August 2001), at the end of the course (December 2001), and 16 months after the end of the course (April 2003). Questionnaires were completed in a classroom with the instructor present. Students were told before the distribution of the questionnaire that the results would not be used in calculating course grades and that the questionnaires would be kept in a sealed envelope by the honors program secretary and not released to the course instructors until after grades were posted. The third time the questionnaire was administered, the students were given $10 per completed questionnaire to use for honors-program extracurricular activities. Exams were coded to track an individual student's performance across exams, and the actual identity of the student was unknown to us. Thirty-one of 38 students (82%) completed the questionnaire the first two times it was administered, and 24 of 38 (63%) completed the questionnaire all three times. Students who did not complete the three questionnaires failed to do so because they enrolled in the course after the first questionnaire had been distributed or because they graduated before the distribution of the third.

The questionnaire consisted of 18 true-false and 10 short-answer content questions, 19 (first two surveys) or 22 (final survey) Likert-scale items on student opinions, and 8 (first two surveys) or 1 (final survey) informational questions about the students. (Item composition and scoring and the original survey instruments are available from http://www.clarkson.edu/~tlangen/A2A/A2A%20links.htm.)

The content questions included true-false and short-answer items addressing students' knowledge of the A2A region environment and the Adirondack Park and general theoretical issues concerning conservation science and ecosystem management. The content questions included some items that required an in-depth knowledge of the topics so that it would be unlikely that students with no previous exposure to the course material would receive a perfect score on the content questions. The opinion questions included (1) 2 items addressing students' interest in and perceived usefulness of the course, (2) 5 items addressing students' self-assessments of their knowledge about the content areas covered in the course, and (3) 12 items addressing students' attitudes about conservation and environmental management, both within the A2A region and nationally. The same questions were asked each of the three times the questionnaire was distributed. Students were never provided feedback on their responses to the questionnaire, and at no time was an answer key or study sheet distributed to students.

When analyzing the data, we created composite scores by summing multiple items that tested the same attribute (i.e., were the same category of question; method of scoring items and item composition of each composite score is available from http://www.clarkson.edu/~tlangen/A2A/A2A%20links.htm). Composite scores were judged reliable when

Table 1. Demographic characteristics of the honors class ($n = 31$) and the control subject pool ($n = 30$).

Demographic category	*Control*	*Honors*
Mean age (years)	21.0	20.1
Proportion male	0.67	0.68
Proportion engineering majors	0.67	0.67
Mean grade point average (0–4)	3.3	3.7
Proportion Adirondack Park county residents	0.27	0.23
Proportion New York state residents	0.83	0.77
Proportion visited Adirondack Park	0.67	0.71
Proportion visited Algonquin Park	0.10	0.13
Proportion member of an environmental organization	0.10	0.06

Cronbach's α (an index of interitem reliability) was at least 0.7 overall and for each item (a standard criterion for users of this index). For opinion questions, responses were recoded so that item responses were all in the same direction.

As a control, sections of the questionnaire were administered twice (August and December 1991) to students in two other Clarkson University classes. The purpose of this control was to verify that any apparent changes in content knowledge or opinions after having taken our course are indeed due to our intervention and not simply due to experiences and events outside the classroom, general changes in knowledge and attitudes with age, or familiarization with the survey questions upon repeated administration of the instrument. The questionnaire was identical to the one administered to the students in our honors course, except that the short-answer content questions and opinion questions about the course were not included. A subject pool of 30 students was created based on the demographic data provided by the questionnaire. Students placed in the constructed subject pool were those who most closely matched the students in our honors course in terms of major field of study, grade point average, and geographic origin (Table 1). The pool was created blind to responses on other items of the questionnaire.

The distribution of subject composite scores for each question category was such that parametric statistical analyses could appropriately be applied (e.g., quasi continuous, normally or uniformly distributed). Results were compared with repeated-measures ANOVA. To compare the control subject pool to the honors course students, the interaction term is reported. If the honors course caused a significant change in knowledge or attitudes, there would be a difference between the pretest and posttest scores for the honors course but not for the control subject pool. To test where significant differences in scores occurred among the three tests (pretest, posttest, 16 months posttest), we used a post hoc test, least-squares mean difference, with the decision criterion $p = 0.05$. Percentage changes are expressed as mean ± SE.

Content Knowledge and Attitudes Results

Content knowledge, as measured by the true-false questions, increased significantly between the beginning and end of the semester for the honors class but not for the control student-subject pool (Table 2; mean improvement: control group = −5 ± 4.1%, honors class = 29 ± 5.3%). The honors program students showed no

Table 2. Comparison of the honors class ($n = 31$) to the control subject pool ($n = 30$) for each of the three question categories administered to both[a].

Question category	*Items*[b]	*Pretest mean*[c] *control*	*Pretest mean*[c] *honors*	*Post-pretest*[d] *control*	*Post-pretest*[d] *honors*	*Range*[e]	F[f]	p[g]
TF content knowledge	18	8.8 ± .032	10.0 ± 0.31	−0.6 + 0.39	2.6 ± 0.43	0–18	32.0	<0.0001
Self-assessment of content knowledge	7	17.7 ± 0.83	16.2 ± 0.82	−0.9 ± 0.69	9.8 ± 0.89	7–35	89.4	<0.0001
Environmental attitudes	10	33.9 ± 0.61	33.9 ± 0.86	−0.5 ± 0.63	0.1 ± 0.77	10–50	0.4	0.5

[a] *For details on the specific items included in each question category, item scoring, and creation of composite category scores and scales, see http://www.clarkson.edu/~tlangen/A2A/A2A%20links.htm*
[b] *Number of question items summed to create the composite question category.*
[c] *Mean summed score of all items in the question category.*
[d] *Mean change in score between the pretest and posttest.*
[e] *Range of the scale for the summed items.*
[f] *Class x test interaction.*
[g] *Degrees of freedom = 1,58.*

Table 3. Comparison of the scores across the three questionnaires (pretest, posttest, 16-month posttest) completed by the honors class students ($n = 24$) for each of the five question categories.[a]

Question category	*Items*[b]	*Pretest*[c]	*Post pretest*[d]	*Post 16 months pretest*[e]	*Range*[f]	F	p[g]
TF content knowledge	18	10.0 ± 0.39	2.8 + 0.50	1.8 + 0.51	0–18	15.7	<0.0001
Short answer content knowledge	10	32.9 ± 2.57	24.1 + 2.24	18.3 + 2.54	0–100	59.3	<0.0001
Self assessment of content knowledge	7	16.9 ± 0.75	9.5 + 0.99	7.0 + 0.88	7–35	63.4	<0.0001
Assessment of the course	2	7.2 ± 0.34	0.0 + 0.28	0.7 + 0.27	2–10	3.4	0.04
Environmental attitudes	10	34.0 ± 1.01	−0.3 + 0.96	1.5 + 0.83	10–50	2.3	0.11

[a] *For details on the specific items included in each question category, item scoring, and creation of composite category scores and scales, see http://www.clarkson.edu/~tlangen/A2A/A2A%20links.htm.*
[b] *Number of question items summed to create the composite question category.*
[c] *Mean summed score of all items in the question category.*
[d] *Mean change in score between the pretest and posttest.*
[e] *Mean change in score between the pretest and test administered 16 months after the course's conclusion.*
[f] *Range of the scale for the summed items.*
[g] *Degrees of freedom = 2,46.*

significant change in performance on the true-false items between the end of the semester and 16 months later (Table 3; pretest ≠ posttest = 16 months posttest). For the short-answer content questions, the honors students significantly improved between the pretest and the two posttests (Table 3), but the difference was significantly greater between the pretest and posttest (improvement = 108 ± 24.6%) than between the pretest and 16 months posttest (improvement = 82 ± 19.4%).

The results were qualitatively similar when students were asked to self-assess their knowledge about the content areas covered by the course. The honors course students assessed themselves more knowledgeable at the time of the posttest than the pretest, but the control pool was unchanged (Table 2). When we pooled data from the honors course and control subject pool, the change in self-assessment between the pretest and post-test correlated with the change in performance on the true-false content questions (Pearson's $r = 0.44$, $p < 0.001$). Therefore the post-test self-assessment was highly correlated with performance on the true-false content questions ($r = 0.68$, $p < 0.0001$). The honors students significantly increased the self-assessment of their content knowledge between the pretest and posttest (Table 3; mean increase = 64 ± 9.1%), and these self-assessment scores declined slightly between the first posttest and 16 months later (mean change = −8 ± 3.5%) but remained significantly higher than the pretest. These results mirrored the results of the true-false and short-answer content questions.

For the summed opinion questions related to attitudes about conservation and environmental management, there was no difference between the honors program students and the comparison group (Table 2; $F_{1,58} = 0.1$, $p = 0.8$) and no apparent effect of the honors class experience (Table 2). There was no change in attitudes, as assessed by the opinion items on the questionnaire, over the three administrations of the assessment instrument (Table 3). An exploratory analysis of subsets of the questions yielded no indication that responses on specific items or groups of items changed over time either.

At the time of the pretest students were instructed to read the course syllabus and then rate on a Likert scale their interest in the course and the anticipated usefulness of it. Scores on these two items were highly correlated. Students were asked the same questions after having taken the course and 16 months later. There was a significantly more positive response over time (Table 3). In fact, there was no difference between the pretest and posttest assessment (mean change pretest to posttest = 1 ± 5.3%), but the students' evaluations of interest and usefulness increased significantly when measured 16 months after the course than the previous two questionnaires (mean change posttest to 16 months later = 22 ± 12.1%).

In addition to completing the questionnaires we administered, the students were required to complete an official Clarkson University course evaluation at the end of the course. Most courses at Clarkson use traditional pedagogical methods, but there are also a significant number that apply problem-based learning, cooperative-learning, and other innovative teaching approaches. Our course rating was similar to the university average (class mean = 3.7, university mean = 3.8; where very poor = 1.0 and excellent = 5.0); and the rating for level of intellectual challenge was also similar to the university average (class mean = 3.9, university mean = 4.1; where strongly disagree that the course was intellectually challenging = 1.0 and strongly agree = 5.0).

A third narrative assessment of the course was administered by the honors program. Comments were generally positive about all aspects of the course except the volume of reading assignments. Most students who responded commented on how the course opened their eyes to regional environmental issues of which they were largely unaware and that they had learned that conservation planning required a greater range of perspectives and a wider range of stakeholder input than they had believed necessary coming into the course. Several students commented that they were previously unaware that there was "science" behind environmental conservation. Students also commented that they thought the course was effective at teaching skills for multidisciplinary teamwork, which they anticipated would be useful in future endeavors.

The reason for the improvement in assessment of interest and value of the course 16 months after its completion may be indicated by the responses to three items that were added to the third (16 months after course) questionnaire. When asked to evaluate the statement "Over the last year, I have thought about some issues or concepts that I first learned about in this course," the mean response score = 2.5 ± 0.16 on a scale of 1 (never) to 3 (frequently). When asked to evaluate the statement "I have been more aware of environmental issues pertaining to the Adirondack/St. Lawrence Valley region during the past year than before I took the course," the mean response score = 3.5 ± 0.26 on a scale of 1 (strongly disagree) to 5 (strongly agree). When asked to evaluate the statement "I have been more aware of national or global environmental issues during the past year than before I took the course," the mean response score = 3.7 ± 0.19.

Conclusions

Our assessment results indicate that an open-ended, problem-based learning approach to teaching conservation science and environmental management to academically talented, college upperclass students in a general-studies course is effective at improving content knowledge about these subjects and increases student interest and awareness about environmental issues. Students found such a course interesting and valuable, even if they did not voluntarily enroll in it. The results also indicated that such a course may have little direct effect on students' attitudes about controversial issues related to conservation and environmental management.

We compared the effectiveness of a problem-based learning course to no formal instruction on college-student content knowledge and attitudes about conservation science and environmental management. We did not assess whether problem-based learning was more effective than traditional classroom pedagogical approaches. This would have obligated us to teach class sections using each approach, which was impossible in this instance. Moreover, to properly judge the generality of our results, replicate studies by other instructors using problem-based learning approaches to teach courses similar to ours would be required. One purpose of this paper is to encourage educators in the field of conservation biology and related disciplines who are not primarily education researchers to nevertheless seriously assess the outcomes of their courses and other educational programs so as to improve the pedagogy of their own courses and to provide general data as to the effectiveness of traditional and innovative approaches to environmental education. We believe that valid, informative studies can be done in our classes despite constraints that result in some compromises to ideal research design (see D'Avanzo 2000, 2003*a*, 2003*b*; Nazario et al. 2002; McMillan 2003).

Our results support the view that problem-based courses on conservation science and policy do provide a valuable learning experience within the general-studies curriculum of a college undergraduate education, as advocated by Orr (1994) and Bednar (2003). Our results also indicate that such a course can be partially successful at meeting the general objectives of effective environmental education. Students' content knowledge about the environment improved and they became more aware of environmental issues and the value of environmental education, but their opinions related to conservation science and environmental management did not change. Perhaps if monitored over a longer period, we would detect a change in opinion about controversial issues because students were made more aware of environmental issues as a consequence of taking an open-ended, problem-based course and would thus pay more attention to debates surrounding these issues and reassess their own opinions. It may be unrealistic to expect much change in deeply engrained beliefs from the experience of a single college course, no matter how well conceived. Perhaps the best one can hope for is that students become more careful and sympathetic listeners to people with other viewpoints and as a consequence develop more thoughtful and informed opinions about controversial environmental issues.

The course was generally successful at providing an informative and useful experience for students and instructors alike. For other educators who may wish to emulate our approach we suggest the following:

- Select an environmental issue that is complex but for which concrete policy decisions are possible. The A2A corridor initiative was an ideal controversy in this regard.
- Provide detailed guidance on writing white papers and provide exemplar models. Our students had not encountered this form of writing before our class and did not have much experience writing a comprehensive review of science and policy for a general audience. They needed much coaching to do it effectively.
- Present a diversity of opinions in readings, speakers, and other resources. Our students had simplistic, preconceived notions about the views of stakeholders, policy

makers, and academic researchers. By hearing from a diversity of voices, students learned that proponents and opponents to the A2A corridor had much more thoughtful and nuanced opinions and therefore were less polarized generally than the students believed initially.

- Avoid the temptation to assign every relevant reading. We probably erred in assigning too many readings. Consequently students read each less carefully and thoughtfully than we would have liked. In retrospect, it would have been better to assign a smaller quantity of readings and provide others as supplements for further research.
- Challenge extreme opinions and enforce classroom civility. Our students, perhaps reflecting popular culture in the United States, tended to stake out extreme positions to debate and to create overly simplistic and sometimes derogatory characterizations of others' positions (e.g., tree hugger vs. greedy developer). We found it necessary to request that students be respectful of others' opinions and to focus discussions on gaining a deeper understanding of conflicting viewpoints rather than trying to win debate points.
- Constantly monitor students' progress. Despite the fact that there were no graded exams, students were motivated to keep up with the class material via our weekly graded discussions and written reflections. Through these activities we kept track of the intellectual progress of the students and detected and corrected serious misconceptions that arose before the students had begun to draft their white papers.

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